Electrifying TRMs at the Convergence of Decarbonization Policy, Program Delivery, and Evaluation

Kevin Ketchman, Opinion Dynamics, Waltham, MA
Jossi Fritz-Mauer, PSEG Long Island, Melville, NY
Katherine Montijo, TRC Companies, Inc., Melville, NY

ABSTRACT

As states and municipalities adopt decarbonization policies, it is critical that energy efficiency (EE) program administrators, implementers, and evaluators transform their traditional EE programs to capture new goals related to efficiency, electrification, and carbon reduction. Energy efficiency programs often rely on Technical Reference Manuals (TRMs) to document standardized and transparent methods for quantifying energy and demand impacts from EE measures, but few existing TRMs include methods for electrification. Recognizing this gap alongside New York's aggressive goal to achieve zero GHG emissions in the power sector by 2040 (CESA 2021), PSEG Long Island EE program administrators collaborated with their program implementer (TRC) and evaluator (Opinion Dynamics) to "electrify" their TRM. This process revealed a clear need to reframe how TRMs define baseline conditions, broaden the range of equipment selection and replacement scenarios, and define electrification terms for transparent and replicable reporting of program performance.

This paper describes the collaboration process between these key stakeholders and resulting electrified TRM. We (1) Compare the traditional TRM and electrified TRM, including technical differences needing consideration when converting to an electrified TRM; (2) Describe the collaborative process and shared lessons between the program administrators, implementation team, and evaluation team in development of the TRM; (3) Discuss implications of an electrified TRM for program design, implementation, data collection, program performance, and evaluation activities; and (4) Compare the pre- and post-electrification performance in terms of total per measure energy impacts for several electrification measures.

Introduction

The US electric grid offers a potential pathway for decarbonizing buildings' national energy consumption through energy efficiency (EE) and renewable energy generation. Less than a decade ago, Hawaii became the first state in the US to adopt a 100% renewable power source goal for their power sector. By 2019, seven other states as well as Puerto Rico and the District of Columbia had set 100% renewable energy or zero Greenhouse Gas (GHG) emissions goals (CESA 2021). As we enter 2022, 15 states have adopted similar goals to decarbonize their power sector and one state (Massachusetts) has set an economy-wide net-zero emissions goal (CESA 2021). As more utilities and states move towards electrification of buildings and fleets, there is an exigent need for cost-effective and replicable methods of quantifying energy savings from electrification measures, i.e., measures that convert fossil fuel equipment to electric.

Our work transitioning the PSEG Long Island TRM revealed the need to reframe how TRMs define baseline conditions, broaden the range of equipment selection and replacement scenarios, and define electrification terms for transparent and replicable reporting of program performance. Throughout this paper, we identify the crucial and substantive differences between a traditional technical resource manual (TRM) and an electrified TRM, present a collaborative method for transitioning a traditional TRM towards fuel-agnostic metrics of energy (MMBtu) savings in support of decarbonization, and share the key learnings from our experience collaborating to produce the first-of-its-kind comprehensive electrified TRM.

Motivation for Transitioning to an Electrified TRM

In 2018, the New York State Energy Research and Development Authority (NYSERDA) published *New Efficiency: New York*, a revised EE plan for achieving ambitious greenhouse gas (GHG) reductions by 2050 of 80% from 1990 levels (NYSERDA 2018). The *New Efficiency: New York* plan established targets around cumulative annual site energy savings relative to forecasted energy consumption, but rather than use common energy units (e.g., MWh, MW, and therm), the goals were set around British thermal units (Btus) to capture GHG reductions needed to ultimately meet the state's climate goals.

Under the *New Efficiency: New York* plan,[1] utilities' EE program goals are realigned to achieve decarbonization of buildings' energy consumption through EE offerings, resulting in *beneficial electrification*.[2] Fossil fuels tend to have a higher embodied carbon than grid-delivered electricity; consequently, replacing fossil fuel energy use with electricity typically results in reduced greenhouse gas emissions as illustrated in Table 1. This impact is heightened when electricity is generated from low- or zero-carbon sources; however, without continued expansion of renewable generation capacity, fossil fuel-dominant electric grids could potentially negate the decarbonization benefits of electrification (see ReliabilityFirst Corporation [RFC] values in Table 1).

Table 1. Decarbonization of residential sector energy use, sorted by average household annual carbon emissions.

Fuel Source (Geography)	Embodied carbon of fuel source (lb. of CO_2/MMBtu)	Average household annual energy use by fuel (MMBtu)	Average household annual carbon emissions (lb. of CO_2)
Electric Grid (RFC)	283	63.0	17,796
Heating Oil (USA)	161	67.3	10,855
Natural Gas (USA)	117	57.8	6,763
Propane (USA)	139	31.2	4,337
Electric Grid (NPCC)	125	28.0	3,489

Sources: Embodied carbon of fuel (EPA 2016, EPA 2021); Household energy use estimates (EIA 2018) (EPA 2016); RFC-averages for the ReliabilityFirst Corporation region; NPCC- averages for the Northeast Power Coordinating Council region; USA-national average.

Two perspectives emerged as New York began laying out a new vision for EE. First, EE was poised to become a cornerstone of New York State's clean energy and climate plans, and second, the collateral effects for program administrators, such as rethinking EE program offerings, would be crucial as well. In response, PSEG Long Island, began planning for the transition to beneficial electrification with a focus on the TRM, a primary resource for program planning and implementation. While the New York State TRM Committee planned a major update addressing beneficial electrification for the 2021 program year, the

[1] In part, the plan proposes decarbonization is achievable by transitioning buildings' fossil fuel equipment to electric through utility-sponsored EE programs in parallel to increasing the renewable energy generation capacity on the electric grid. This paper focuses on the EE program component of the plan, but briefly touches on the importance of increasing renewable generation capacity in achieving decarbonization goals.

[2] Beneficial electrification refers to the benefits, in the form of reduced energy (MMBtu) and energy-related greenhouse gas emissions, that result from transitioning fossil fuel equipment to electric.

update was not publicly filed until August 2020, months after PSEG Long Island and their implementer, TRC, needed to finalize plans for the upcoming program year. Without TRM guidance on quantifying beneficial electrification across all measures and products, PSEG Long Island needed innovative ways to value its current repertoire of energy-efficient products and measures. Additionally, they needed to find the correct future mix of strategies to comply with state energy savings targets.

TRC understood the challenge was greater than implementing the program. It also required reframing the traditional electric utility approach around unconventional fossil fuel offerings intended to prioritize GHG reductions and reduce reliance upon fossil fuels. This meant exploring new measure offerings and challenged TRC to consider options that didn't exist before and the methods needed for measuring success. Implementing a first-of-its-kind beneficial electrification program provided the opportunity to be a positive example, set precedents, and pave the way for electric utilities and beneficial electrification methodologies.

Given the distinct uses and disparate needs of utilities, implementers, and evaluators have in relation to a TRM, creating or amending a TRM requires involvement and deliberation from all key stakeholders. When transitioning an existing TRM to an electrified TRM, cooperative collaboration is essential and begins with identifying shared goals that consider the contrasting and potentially competing priorities of each stakeholder.

Goal Setting

The goal of a TRM is to derive reproducible and defensible energy savings resulting from the installation of energy-efficient measures. The ability of a TRM to achieve this goal is partially determined by identifying and defining of key performance metrics (e.g., energy savings), underlying assumptions (e.g., standard baselines and differences in program design), and methodological rigor (e.g., detail of algorithms and generalization of parameter assumptions).

When defining key performance metrics, look to state regulatory requirements. In New York, the push to electrify buildings resulted in the move from electric (kWh) and natural gas (therm) energy reduction goals to fuel-neutral units of energy (Btu) and decarbonization (e.g., $CO_{2\text{-eq.}}$). This change in regulatory requirements was the driving force behind transitioning PSEG Long Island's TRM. The team collaboratively understood this goal, and as a result, worked to convert the entire TRM to quantifying energy savings for all measures in units of Btus. This included non-beneficial electrification measures, like LED lighting and energy-efficient motors.

TRMs generally set overarching baseline assumptions for use throughout the measures. This predominately takes the form of building energy codes but are sometimes developed for different program delivery designs. In this study, the team aligned with the effective New York state building code, which at the time of the study was the 2015 International Energy Code Council and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 90.1-2013 codes (IECC 2014; ASHRAE 2013). Assumptions on the appropriate baselines were made during development of each measure, based on the program design, such as the targeted mix of existing equipment being replaced. The evaluation team checked for consistency of assumptions across the measures.

At the individual measure-level, it is important to consider the implementation team's data collection burden when developing algorithms and parameter assumptions. The rigor of algorithms and assumptions may negatively impact the TRM's applicability if the implementation team is unable to collect the detailed data the algorithms need. It is also important to consider the impact on an algorithm's savings estimates when field-collected data is unavailable. When holding discussions on data needs, running a parametric sensitivity analysis can differentiate between the parameters that are critical to cost savings and those that can instead rely on generalized assumptions.

For example, a common practice for calculating ASHP energy savings is to use the system's specification output capacity for heating and cooling. This term acts as a benchmark for the total potential heat an ASHP can supply to a building; however, it assumes that the ASHP unit is correctly sized to meet the heating and cooling loads of a building. An alternative approach is to calculate a building-specific heating load using the Air Conditioning Contractors of America Manual J calculation workbook (ACCA 2021). While this approach can improve the accuracy of estimated savings, it requires additional data collection, such as building volume, window surface area, and infiltration rates. The increased data may inadvertently inhibit the implementers' use of the measure, impact overall program performance, and increase evaluation costs for measurement and verification.

For this study, goal-setting discussions occurred between the project partners at the outset of the study and continued throughout. As the team progressed and began implementing the new TRM structure to existing measures, new questions emerged that were isolated to one measure and other questions arose that were farther reaching. The collaborative team maintained open channels of communication and remained receptive to changing dynamics, which was crucial for this engagement to electrify PSEG Long Island's TRM. In the following sections, the authors define an electrified TRM, discuss the major components, compare those to a traditional TRM using the PSEG Long Island TRM as an example.

What is an "Electrified" TRM?

The US Department of Energy (DOE) defines a traditional TRM as, "*a technical resource that contains energy efficiency measure information used in program planning, implementation, tracking, and reporting and evaluation,*" and includes information on "*deemed energy and demand savings values for measures, engineering algorithms to calculate energy and demand savings, and variables and factors, such as measure life information and hourly load shapes used, for calculating impacts*" (Schiller, Leventis, Eckman, et al. 2017). Reflecting DOE's definition, the authors define an "electrified" TRM as a having many of the same qualities of a traditional TRM—standardized methods that are well-documented and replicable—but with the notable nuance that energy savings algorithms should be inclusive of energy flows across fuels.

While no TRM has holistically adopted beneficial electrification outside of the PSEG Long Island TRM, recent TRM revisions are incorporating electrified measures in jurisdictions across the country as electrification policies are enacted (NYSJU 2020, IL SAG 2020, PA PUC 2021, Mass Save 2018). Four additional TRMs have or are expected to adopt electrification measures within the year (Table 2).

Table 2. Summary of TRMs currently (effective as of 2021) or expected to begin employing electrification calculations, including positive (+) and negative (-) elements of each.

Technical Reference Manual	Electrification End-Use	Notes on TRM assumptions and algorithms
PSEG Long Island 2021 TRM (Adopted 2020)	Comprehensive	(+) Clear guidance on baselines assumptions for electrification and non-electrification scenarios (+) Algorithms do disaggregate changes in fuel source consumption (+) Does distinguish equipment performance and operational characteristics by technology
New York Statewide TRM v8 (Adopted 2020)	Res and C&I HVAC Res DHW	(+) Clear guidance on baselines assumptions for electrification and non-electrification scenarios (-) Algorithms do not disaggregate changes in fuel source consumption, but practitioners could do so if desired (-) Does not distinguish effective full load heating (EFLH) value by technology

Technical Reference Manual	Electrification End-Use	Notes on TRM assumptions and algorithms
Illinois Statewide TRM v9 (Adopted 2020)	Res HVAC	(+) Algorithms do disaggregate changes in fuel source consumption (+) Includes a *Heat Rate of Grid* term (Btu/kWh) for converting between kWh and therms (-) Does not distinguish EFLH value by technology
Pennsylvania Statewide 2021 TRM (Adopted 2019)	Res HVAC	(+) Separates electrification and non-electrification scenarios into unique measures (+) Does distinguish EFLH value by technology
Massachusetts (Expected adoption 2022)	TBD	Massachusetts set ambitious GHG reduction goals for the next three-year (2022-2024) Mass Save Energy Efficiency Plan. The current 2019-2021 TRM does not address electrification.

Sources: NYSJU 2020, IL SAG 2020, PA PUC 2021, Mass Save 2018

As with traditional TRMs, electrified TRMs reflect the needs and priorities of the key stakeholders involved in the creation process. Whether it addresses specific end-use scenarios, as with the recent New York, Illinois, and Pennsylvania TRMs, or is an exhaustive revision, an electrified TRM expands the range of replacement scenario assumptions beyond those in a traditional TRM.

Replacements of inefficient equipment are commonly assumed to be 'like-for-like' replacements with a high-efficiency unit of the same fuel type (e.g., furnace for a furnace) in traditional TRMs. While 'like-for-like' assumptions support easy application and interpretation of TRM measure assumptions and algorithms, they do not support beneficial electrification program designs. An electrified TRM, in addition to 'like-for-like,' adds other potential beneficial electrification replacement scenarios, as long as the new electric equipment returns positive energy (MMBtu) benefits from replacing fossil fuel equipment.

Measures in a Traditional vs. Electrified TRM

Both traditional and electrified TRMs contain EE measures to provide TRM practitioners with guidance on eligibility criteria and general assumptions applicable to different program designs. Measures also provide the energy savings algorithms, parameter assumptions, and baseline equipment characteristics required to estimate energy savings.

Beneficial electrification expands the range of potential measure offerings through one of two ways: (1) Additional replacement scenarios within existing measures, such as fossil fuel-to-electric commercial kitchen equipment; or (2) New measures not traditionally available through programs, such as gasoline to electric lawn equipment measures. As a result, beneficial electrification measures remove carbon from the grid by eliminating the use of fossil fuels, but in addition to the decrease in fossil fuel consumption, these measures lead to a proportional increase in electricity consumption.

In an electrified TRM, energy algorithms capture both the savings resulting from improvements to equipment efficiency (*energy efficiency algorithms*) as well as the change in electric and fossil fuel consumption resulting from the transitioning of fossil fuel equipment to electric (*beneficial electrification algorithms*). This methodology makes it possible to quantify changes in electricity and fossil fuel use, and later convert energy to GHG reductions. However, this method also adds a layer of complexity to algorithms and assumptions that requires added scrutiny by evaluators to ensure calculations do not "double dip" or misrepresent energy flows between equipment.

The potential for inadvertent double dipping is lessened by establishing key terms and definitions to ensure clarity in communication and reporting between program administrators, implementers, and evaluators. Table 3 summarizes the key terms and their definitions used in the PSEG Long Island TRM, which are discussed in detail in the following sections.

Table 3. Key algorithm terms and definitions used in the PSEG Long Island TRM.

Term	Definition
kW	Peak coincident demand electric savings.
kWh_ee	Electric energy savings associated with energy efficiency improvements of installed equipment over the baseline electric equipment.
kWh_be	Beneficial Electrification electric energy impacts associated with installed electric equipment replacing fossil fuel equipment. With fuel switching measures, this represents an increase in kWh consumption.
ΔkWh	Total electric energy impact equal to kWh_ee minus kWh_be.
MMBtu_ee	Fossil fuel energy savings associated with energy efficiency improvements of installed equipment over the baseline fossil fuel equipment plus kWh_ee converted to MMBtu.
MMBtu_be	Beneficial Electrification fossil fuel energy savings associated with removed fossil fuel equipment replaced by electric equipment minus kWh_be converted to MMBtu.
MMBtu_total	Total energy impact equal to the sum of MMBtu_ee and MMBtu_be.

Once the key terms and definitions are established, they are utilized to create the assumptions and guidance that all TRMs provide through the use of energy efficiency algorithms, beneficial electrification algorithms, and parameter assumptions.

Energy Efficiency Algorithms in a Traditional vs. Electrified TRM

All measures within TRMs, electrified or otherwise, are designed to reduce an end-user's energy consumption through replacement of less-efficient equipment (i.e., baseline case) with higher-efficiency units (i.e., efficient case). Usually, measure algorithms calculate savings based on differences in performance characteristics between the baseline and efficient equipment, such as seasonal energy efficiency ratio (SEER) for cooling equipment or heating seasonal performance factor (HSPF) for electric heating equipment.

For example, a traditional TRM typically defines the baseline equipment for an air source heat pump (ASHP) measure as a like-for-like ASHP replacement or as a central air conditioner (CAC) with electric resistance heating, in effect restricting beneficial electrification of fossil fuel furnaces. To address homes with CAC and fossil fuel furnace HVAC systems, the traditional TRM treats the equipment independently through a CAC upgrade separate from a fossil fuel furnace upgrade, without guidance for beneficial electrification improvements.

Conversely, in an electrified TRM, improvements in energy efficiency are captured in two terms: kWh_ee and MMBtu_ee (Table 3). The kWh_ee term represents the energy efficiency improvement of electric equipment, while the MMBtu_ee term represents the fossil fuel efficiency savings, plus kWh_ee converted to MMBtu. When replacing a CAC with an efficient ASHP and supplementing a fossil fuel heating system, the electric energy efficiency savings (kWh_ee) directly correlates to the difference between the baseline CAC and efficient ASHP unit SEER.

Beneficial Electrification Algorithms

TRMs are designed to return an energy savings value that is positive, although technically a reduction in energy consumption. In an electrified TRM, however, not all algorithms result in a reduction of electric usage. Notably, kWh_be is an increase in electricity consumption and is subtracted from kWh_ee when calculating total change in electricity (ΔkWh). The importance of maintaining proper accounting of positive and negative impacts is key to correctly reporting energy impacts and total energy savings.

Parameter Assumptions

Due to the “like-for-like” replacement assumption employed by traditional TRM, operational characteristics, such as effective full load hours (EFLH), do not change between the baseline and efficient scenarios . Since an electrified TRM, opens the door to a number of baseline equipment combinations; however, operational characteristics will inevitably differ between the scenarios. Therefore, it is critical to compare actual baseline performance characteristics and not focus solely on the end use, as was done historically.

Table 4 illustrates the culmination of the electrified TRM algorithms using an ASHP example under three different replacement scenarios.

Table 4. Beneficial electrification impacts for different ASHP replacement scenarios following the electrified PSEG Long Island TRM

Replacement Scenario	kWh_ee	kWh_be	ΔkWh	MMBtu_ee	MMBtu_be	Total MMBtu Saved
ASHP replacing CAC and fossil fuel heating	504	5,324	-4,820	1.13	49.1	50.3
ASHP replacing fossil fuel heating, no prior cooling	351	5,324	-4,973	0.6	49.1	49.7
ASHP replacing CAC and electric resistance heating	11,254	0	11,254	38.4	0.0	38.4

Throughout the process of defining and creating the terms, algorithms, and assumptions of an electrified TRM, cross-team collaboration is crucial to ensure the impacts of this multifaceted endeavor are considered from the perspectives of program administrators, implementer, evaluator, and other key stakeholders. For example, adding fossil fuel baseline scenarios for an ASHP measure may increase the implementer’s data collection efforts, because the existing TRM assumes “like-for-like” code baselines, thereby not requiring information on existing equipment. This is especially relevant when it comes time to transition existing measures in a traditional TRM to an electrified TRM.

Transitioning Select Existing Measures

For the PSEG Long Island TRM, the study team chose to strategically implement the electrified TRM approach for a select group of measures. This allowed all parties to more thoroughly consider the goal-setting decisions made in a practical application. Importantly, this step also afforded the team an opportunity to modify earlier decisions before course corrections could be overly burdensome.

The team identified heat pump technology as a priority technology for achieving the decarbonization goals set forth in the *New Efficiency: New York* plan. Beneficial electrification changed the way TRC looked at ASHPs. While heat pumps had been offered in the PSEG Long Island EE portfolio since 2010, savings were derived from an inefficient heat pump baseline and did not capture beneficial electrification from displacing fossil fuel. Under beneficial electrification, the displaced fossil fuel reductions could be claimed, increasing the cost-effectiveness of the measure, and ultimately enabling the utility to invest more budget and rebate dollars in the promotion of ASHPs.

Air source heat pumps are now promoted as a primary heating source under the cold climate ASHP (ccASHP) offering—a newer technology capable of heating homes in colder climates. Other measures included in this strategic implementation were ductless mini-split heat pumps (DMSHP) and domestic hot water heat pumps (HWHP). The process of transitioning these measures involved the development of beneficial electrification algorithms and the underlying assumptions, notably for a breadth of baseline equipment and fuel mixes.

The team leveraged previously established algorithms and assumptions to develop seven unique scenarios that encompassing a mix of existing HVAC system configurations and replacement types, and corresponded to the program's delivery scenarios, summarized in Table 5.

Table 5. Air Source Heat Pump Measure Scenarios Incorporated into the Electrified TRM

Replacement type	Baseline HVAC system configuration	Beneficial electrification
Early retirement	Electric resistance heat and central air conditioning	No
Early retirement	Fossil fuel furnace and no air conditioning	Yes
Early retirement	Fossil fuel furnace and central air conditioning	Yes
Early retirement	Electric heat (mix of ASHP and electric resistance) and central air conditioning	No
End of life/new construction	ASHP without supplemental fossil fuel heating	No
End of life/new construction	ASHP with supplemental fossil fuel heating	No
End of life/new construction	Fossil fuel heating and central air conditioning	Yes

Coinciding with the PSEG Long Island TRM electrification, NYSERDA completed residential and commercial building stock baseline studies across the state. The team used this resource in deriving baseline equipment performance and fuel mix assumptions for HVAC and DHW measures. Without this data, scarce information on the prevalence of delivered fuels' (e.g., propane and kerosene) and aggregate equipment data for the PSEG Long Island jurisdiction would have been a limiting factor to the development of comprehensive beneficial electrification measures. Due to the work that NYSERDA had done, however, the study team was also able to incorporate new measures inclusive of a wide range of fossil fuels.

Creating New Measures

The PSEG Long Island TRM study team expanded the structure to the rest of the TRM, and importantly, created new opportunities through the TRM for decarbonization and energy savings. Under the *New Efficiency: New York* policy, utilities and their implementing partners across the state could expand their program offerings, "utility portfolios will include more comprehensive energy efficiency measure mixes" (NYSERDA 2018). The PSEG Long Island TRM electrification team leaned into this opportunity and developed novel measures that supported decarbonization.

The team developed beneficial electrification measures for residential and commercial applications of heat pump pool heaters, lawn equipment (e.g., lawn mower, leaf blower, weed trimmer), and heat pump water heaters. Relegated to commercial applications only, the team also developed measures for variable refrigerant flow (VRF) heat pumps, nonroad vehicle electrification, and commercial kitchen cooking equipment (e.g., steamers, fryers, ovens). Lastly, the team developed a beneficial electrification measure for residential clothes dryers. The extent and number of new opportunities for decarbonization and energy savings in a given electrified TRM will vary based on the region as well as the priorities of key stakeholders. Below, we provide additional insight on the development of lawn and commercial cooking equipment beneficial electrification measures as they are both common energy-intensive activities across most regions of the US and illustrative of new measures and energy savings opportunities provided by beneficial electrification.

Lawn Equipment

In 2011, roughly 121 million pieces of gasoline lawn and garden equipment were actively employed across the country, representing 20.4 million tons of CO2 emissions annually (Banks 2015). Yet, upon a review of TRMs, the PSEG Long Island study team could not find existing algorithms or assumptions appropriate for modification in an electrified TRM. Consequently, development of this measure required secondary research on lawn equipment operational characteristics, such as average annual operating hours (e.g., time spent mowing lawns), battery runtime to estimate the number of charging cycles, and fuel utilization factors to quantify fossil fuel reductions. Additionally, the study team employed the EPA's Nonroad Technical Reports, which include analysis and results of nonroad emissions sources (EPA 2018). This is not a typically referenced resource in TRMs and illustrates a broader take-away from decarbonization in that the scientific resources we, as an industry, commonly use today will not be the only resources we use tomorrow.

Commercial Kitchen Cooking Equipment

Food service (i.e., restaurants including fast food) represents the most energy intensive building activity in the commercial sector (EIA 2015).[3] Within food service, fossil fuel cooking equipment makes up nearly a third of the energy consumption. While it is challenging to get restaurants to convert from natural gas to electric there is substantial potential for decarbonization within this commercial sector. As a result, the PSEG Long Island study team developed beneficial electrification measures for electric steamers, griddles, fryers, and convection ovens, widely used commercial cooking equipment.

Unlike lawn equipment, the study team did not have to start from scratch for this new measure. The NYS TRM v8 contains commercial cooking equipment measures for natural gas and electric equipment, but not guidance on fuel-switching. This measure provided the foundation of the beneficial electrification measures in the electrified TRM. The team disaggregated the existing algorithms, reshaped them into the beneficial electrification structure, and verified the appropriateness of the previously established assumptions for the new measures. We provide a comparison of energy savings following a like-for-like approach in the NYS TRM v8 and the beneficial electrification approach in the PSEG Long Island electrified TRM in Table 6 and Table 7.

Table 6. Energy savings from like-for-like commercial cooking equipment replacement following the NYS TRM v8, with all units reported in MMBtu for comparison.

Equipment	Annual electric energy savings, *ΔkWh* (MMBtu)	Annual fuel energy savings, *ΔMMBtu*	Total MMBtu Saved
Convection oven, electric	6.3	0.0	6.3
Fryer, electric	8.1	0.0	8.1
Griddle, electric	7.8	0.0	7.8
Convection oven, gas	0.0	13.7	13.7

[3] The top three principal building activities by energy use intensity (kBtu/ft^2) is food service at 282.7, followed by food sales (i.e., grocers) at 209.5, and health care at 172.7 kBtu/ft^2.

Fryer, gas	0.0	38.6	38.6
Griddle, gas	0.0	13.1	13.1

Note: Equipment Scenario assumes baseline equipment is of same fuel source in accordance with the NYS TRM v8 (NYSJU 2020).

Table 7. Energy impacts from beneficial electrification of fossil fuel cooking equipment following the PSEG Long Island electrified TRM, with all units reported in MMBtu for comparison.

Equipment	kWh_ee (MMBtu)	kWh_be (MMBtu)	ΔkWh (MMBtu)	MMBtu_ee	MMBtu_be	Total MMBtu saved
Convection oven	0.0	(14.2)	(14.2)	0.0	29.2	15.0
Fryer	0.0	(36.0)	(36.0)	0.0	84.8	48.8
Griddle	0.0	(30.4)	(30.4)	0.0	74.6	44.2

Note: No energy efficiency fossil fuel savings (MMBtu_ee) result since fossil fuel equipment is replaced with electric.

The tables illustrate the differences in calculating and accounting for changes in energy flows between a traditional and electrified TRM:

- The net electric impact on energy and demand is negative in the electrified TRM.
- The total MMBtu savings is typically larger in the beneficial electrification measures.

These differences are the result of the TRMs underlying assumptions on the baseline equipment. The NYS TRM v8 does not explicitly state in the measure that beneficial electrification is not applicable, however, the general assumption is like-for-like so the energy savings are strictly calculated based on energy efficiency improvements of the installed high efficiency unit over the comparable baseline condition. The comprehensive electrified TRM provides guidance on calculating changes in energy use between fuel sources, enabling practitioners to capture the larger energy savings associated with converting natural gas equipment to electric; natural gas cooking equipment tends to have higher annual consumption and lower efficiencies than electric (NYSJU 2020).

Cost-Effectiveness Screening

Beneficial electrification will require implementers to shift their process of screening projects and revamp of their portfolio screening tool to account for energy flows between fuels and the resulting GHG reductions. For TRC, it was a seismic shift in the way they looked at the efficiency portfolio and introduced potential new measures in both the residential and commercial portfolios that performed well in screening. Those measures included instantaneous water heaters, pool heaters, pool covers, golf carts, forklifts, and, of course, lawn equipment, all of which are common on Long Island with its low-density suburban land use. As mentioned previously, the specifics of regions, state regulations (included cost-effectiveness tests required), and key stakeholder priorities will impact the viability of potential new measures made available by beneficial electrification. Beneficial electrification will impact cost-effectiveness screening across the board, however, regardless of other differences across the country.

For a detailed analysis of the validity and relevance of cost-effectiveness screening under beneficial electrification, see the accompanying paper published in the 2022 International Energy Program Evaluation Conference (Wilson and Sellner 2022).

Conclusions and Recommendations

The *New Efficiency: New York* challenge is reflective of the shift across the US to focus on the reduction of greenhouse gas emissions when establishing climate goals and regulations. This change offers EE programs an opportunity to holistically approach and solve societal problems, and an electrified TRM provides the roadmap to claim associated savings. An electrified TRM focuses on MMBtu reduction targets, and its development allowed the utility, implementer, and evaluator to collectively take a step back and look outside of the microcosm of individual projects and focus on what really matters—greenhouse gas reductions.

Motivated by NYSERDA's *New Efficiency: New York* plan for refocusing EE programs around decarbonization, PSEG Long Island, TRC ,and Opinion Dynamics successfully transitioned an existing traditional TRM into an electrified TRM. In order to do so, the study team developed first generation terminology and algorithms that enabled quantification and accounting of beneficial electrification energy efficiency improvements, and ultimately a roadmap for implementing similar TRM transitions elsewhere.

Reflecting on our shared experience, the authors have the following recommendations for others planning or beginning the process of creating an electrified TRM:

- Develop clear definitions and goals for the TRM through collaborative goal setting. This ensures all stakeholders strive for common objectives, while considering the needs and priorities of individual stakeholders, which facilitates a smooth transition and more meaningful conversation focused on critical elements, such as implications of program design on replacement scenarios.
- Collaborate with the implementer to understand data limitations when transitioning select prioritized measures towards fuel-agnostic metrics of energy (MMBtu) savings and creating new beneficial electrification measures. An electrified TRM potentially increases data collection requirements, which has implications on the implementer's operations and potentially program performance. Understanding the limitations of data collection has a two-fold effect of minimizing gaps in program tracking data used in evaluation and identifying the parameters that require assumptions for when information is not available.
- Identify primary data sources for fossil fuel equipment prevalence. An electrified TRM will require development of assumptions for an array of fossil fuel equipment, including delivered fuels like propane or kerosene. Depending on the scope of the TRM (e.g., statewide or jurisdictional), data may be scarce, and might be a limiting factor to developing a comprehensive electrified TRM.

While we approached electrification in a different way than some of our peers, we are hopeful that the precedent we set will lead others towards incentivizing measures that contribute to a holistic positive environmental impact.

References

ACCA. 2021. "Manual J - Residential Load Calculation." American National Standards Institute and Air Conditioning Contractors of America Association (8th edition)

ASHRAE. 2013. "ANSI/ASHRAE/IES Standard 90.1-2013 - Energy Standard for Buildings Except Low-Rise Residential Buildings." October 2013. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Georgia

Banks, J. L. 2015. "National Emissions from Lawn and Garden Equipment" U.S. Environmental Protection Agency https://www.epa.gov/sites/default/files/2015-09/documents/banks.pdf

CESA (Clean Energy States Alliance). 2021. "Map and Timelines of 100% Clean Energy States." *100% Clean Energy Collaborative*. Last Updated: November 17, 2021. https://www.cesa.org/projects/100-clean-energy-collaborative/guide/map-and-timelines-of-100-clean-energy-states/

Illinois Energy Efficiency Stakeholder Advisory Group (SAG). 2020. "2021 Illinois Statewide Technical Reference Manual for Energy Efficiency Version 9.0"

International Code Council. (2014). 2015 International Energy Conservation Code. ISBN: 978-60983-486-9. published May 30, 2014

Mass Save (October 2018) "Massachusetts Technical Reference Manual for Estimating Savings from Energy Efficiency Measures" (2019-2021 Plan Version)

NYSERDA (April 2018) "New Efficiency: New York" Department of Public Service https://www.nyserda.ny.gov/About/Publications/New-Efficiency

NYSJU. 2020. "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs – Residential, Multi-Family, and Commercial/Industrial Measures." Department of Public Service. Version 8.

Pennsylvania Public Utility Commission (PUC). 2021. "Technical Reference Manual." (2021 edition)

Schiller, S. R., G. Leventis, T. Eckman, and S. Murphy. 2017. "Guidance on Establishing and Maintaining Technical Reference Manuals for Energy Efficiency Measures." Prepared by Lawrence Berkeley National Laboratory for the State and Local Energy Efficiency Action Network.

U.S. EIA. 2015. "Commercial Buildings Energy Consumption Survey (CBECS): 2012 CBECS Survey Data." https://www.eia.gov/consumption/commercial/data/2012/

U.S. EIA. 2018. "Residential Energy Consumption Survey (RECS): 2015 RECS Survey Data." https://www.eia.gov/consumption/residential/data/2015/

U.S. EPA. 2016. "Greenhouse Gas Inventory Guidance: Direct Emissions from Stationary Combustion Sources." Appendix A. pp 17-21.

U.S. EPA. 2018. "Nonroad Technical Reports". https://www.epa.gov/moves/nonroad-technical-reports

U.S. EPA. 2021. "2019 Emissions & Generation Resource Integrated Database (eGRID)" https://www.epa.gov/egrid

Wilson, J., T. Sellner. 2022. "Magnitude Matters: Re-evaluating Traditional Cost-effectiveness Practices for Electrification." 2022 International Energy Program Evaluation Conference, San Diego, CA. January 19-21, 2022