Magnitude Matters: Re-evaluating Traditional Cost-effectiveness Practices for Electrification

Tyler Sellner, Opinion Dynamics, Boston, MA
Jayden Wilson, Opinion Dynamics, Portland, OR

ABSTRACT

Heating electrification offers utility customers an opportunity to save money, increase comfort, and improve their health, while also making significant contributions to carbon reduction goals. It is vital that heating electrification programs are evaluated for cost-effectiveness in a manner consistent with other distributed energy resources and appropriately considering their potential grid impacts. Heating electrification introduces an upside-down world of negative savings, shifting load profiles, and increased prevalence of distributed energy resources (DERs). As such, heating electrification programs will require new approaches to benefit-cost analyses and avoided cost calculations to ensure their application remains theoretically sound. In this new paradigm, how we define benefits, how we allocate benefits temporally, and how we incorporate new value streams (such as carbon emissions reductions) must evolve. In this paper, we will document the existing distortions and applied solutions to effective electrification cost-effectiveness analysis. Inconsistency in how benefits and costs are counted can make a real difference in measure-level benefit-cost ratios (BCRs), potentially leading to erroneous comparisons.

Introduction

Heating electrification offers utility customers an opportunity to save money, increase comfort, and improve their health, while also making significant contributions to carbon reduction goals. It is vital that heating electrification programs are evaluated for cost-effectiveness in a manner consistent with other distributed energy resources and appropriately considering their potential grid impacts. Heating electrification introduces an upside-down world of negative savings, shifting load profiles, and increased DERs. As such, heating electrification programs will require new approaches to benefit-cost analyses and avoided cost calculations to ensure their application remains theoretically sound.

In this new paradigm, how we define benefits, how we allocate benefits temporally, and how we incorporate new value streams (such as carbon emissions reductions) must evolve. In this paper, we will document the existing distortions and applied solutions to effective electrification cost-effectiveness analysis. We will compare heating electrification measures to traditional energy efficiency and fuel-switching measures and characterize why heating electrification is in a new measurement class.

Heating electrification presents fundamental challenges to how we analyze the cost-effectiveness of energy efficiency and related program interventions. Electrification programs result in increased electricity consumption, more commonly categorized as "negative savings" in the traditional energy efficiency paradigm, which poses contradictions to traditional definitions of costs and benefits and how we monetize those value streams. The decision to categorize monetized increased electric consumption as "negative benefits," or costs, results in different benefit-cost ratio results. The concept of negative savings is certainly not new to benefit cost analysis (BCA), or even BCA in traditional energy efficiency evaluation. However, the magnitude of negative savings associated with heating electrification exacerbates existing distortions and presents unique circumstances that warrant revisiting how these savings are addressed in cost-effectiveness analysis. The impact of negative savings on the cost-effectiveness results of a program or portfolio may be minimal as heating electrification remains nascent, but it is important to update frameworks to address electrification now to ensure we are valuing these measures and programs appropriately when they begin to reach scale.

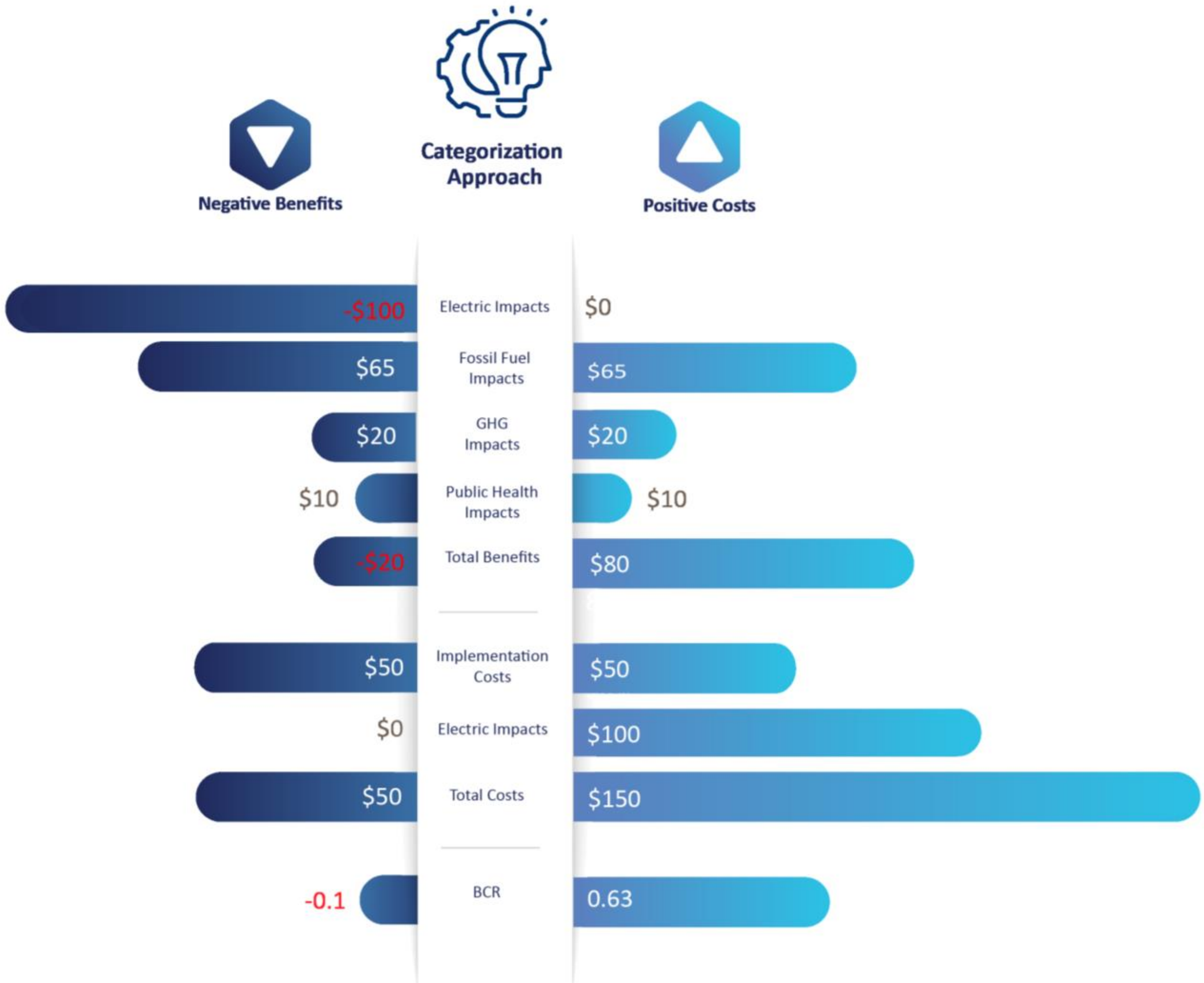
Costs or Negative Benefits?

By their nature, heating electrification programs lead to more drastic changes in energy usage from a single-fuel perspective, compared to traditional scenarios where one might see negative savings: cross-fuel heating penalties and combined heat and power ("CHP") projects. Like heating electrification, measures producing cross-fuel heating penalties and CHP projects result in increased consumption of one fuel and decreased consumption of another. In many jurisdictions, a "net benefits" approach is applied to cost-effectiveness analysis for these scenarios, where negative savings remain on the benefits side of the equation as "negative benefits," rather than being moved to the cost side of the equation.

Inconsistency in how benefits and costs are counted can make a real difference in measure-level or even program-level benefit-cost ratios (BCRs), potentially leading to erroneous resource comparisons. While it is common for benefits to represent net fuel savings, oftentimes the negative fuel benefits (e.g., interactive effects) are small. With heating electrification programs, the negative electric benefits (i.e., increased electric usage) are considerably larger. Accounting for these impacts as either "costs" or "negative benefits" can have substantial effects on BCRs.

Consider a fictional electrification program that costs $50 to implement, increases electricity usage by $100, saves $65 in fossil fuel impacts, and produces $30 in societal benefits. This program could have a BCR of 0.63 or -0.1, depending on how the increased electric usage is accounted for in the analysis (Figure 1). These two BCRs send very different messages to regulators and utility staff. While a BCR below one indicates the costs of an investment exceed the benefits, a BCR above zero signals that positive outcomes result from the investment. A negative BCR, however, indicates that an investment produces results that are counterproductive to the intended outcomes. Said differently, a BCR above zero but below one indicates the investment produced negative net benefits, while a BCR below zero indicates the investment produced negative benefits.

Figure 1. BCA distortions associated with negative savings



By not providing explicit guidance on how to categorize the impacts of electrification, regulators leave cost-effectiveness analysis of these programs open to path dependency. Many cost-effectiveness tools are set up to ultimately calculate a portfolio level benefit cost ratio. Without policy guidance on the treatment of negative savings, it is likely some analysts may unintentionally "net out" negative savings by leaving those savings on the benefit side of the equation, some may recategorize the negative benefits as costs, and others may recognize the conflict presented by electrification measures but determine the impact of negative savings to be too small to warrant overhauling the mechanics of an existing BCA tool. The impact of negative savings on the cost-effectiveness results of a program or portfolio may be minimal as electrification remains nascent, but it is important to update frameworks to address electrification now, to ensure we are valuing these measures and programs appropriately when they begin to reach scale.

Notably, guidance on how to treat negative savings is also unclear in the available benefit-cost literature. Early cost-effectiveness literature from California stated that a key best practice was to always treat benefits and costs as positive values—i.e., a negative benefit should be treated as a cost (Tsui, Stiegelman, and Witting 2016). The National Standard Practice Manual for Benefit-Cost Analysis of Distributed Energy Resources (NSPM for DERs) is somewhat ambiguous in its discussion of electrification impacts and stops short of discussing how to treat negative savings within the mechanics of BCR calculations. For example, the document notes that electrification resources often increase electric system costs, which can be interpreted to mean negative savings from electrification should be treated as costs (NESP 2020). However, the document later states that the inclusion of other benefits associated with electrification technologies, such as Demand Response, can "reduce" added costs resulting from electrification, which could be interpreted as a suggestion to use a "net benefits" approach (NESP 2020).

As electrification programs grow in importance within portfolios, program administrators and regulators should reconsider treatment of the electric costs of the programs and ensure consistency across the broader portfolio of DERs being deployed in their jurisdiction (e.g., energy efficiency, demand response, managed EV charging, and building electrification). Existing cost-effectiveness tools and frameworks can be unwieldly and burdensome; they are often “living” documents in the sense that prior versions are modified and adapted as the needs and requirements of a jurisdiction and stakeholders evolve. Changing fundamental elements of how costs and benefits are recorded is potentially a difficult and time-consuming undertaking, but it is important that jurisdictions are deliberate as opposed to leaving it ambiguous. Heating electrification can result in negative benefits at varying levels of analysis. For example, replacing an old fossil fuel furnace and inefficient central air conditioner (CAC) with an efficient heat pump could result in electric cooling savings while adding electric heating consumption; that heat pump might be installed as part of a larger HVAC program that, overall, results in net electricity savings. Therefore, the decision to recategorize added consumption as a cost at the end-use (e.g., treating negative heating savings as a cost and positive cooling savings as a benefit), measure (e.g., taking the net of the cooling and heating savings), or program level will produce different results and require different levels of updates within a cost-effectiveness tool. Regulators need to provide clear guidance on whether these changes need to be made so the proper time and planning can be allocated to these updates.

Temporal Distortions Methodology

To calculate the results referenced in the following section, we used mostly generalized inputs to illustrate the distortions introduced by heating electrification programs. As presented in Table 1, we utilized Massachusetts-specific avoided costs and load shapes in combination with savings calculated using the applicable algorithms in the PSEG Long Island TRM to develop annual, quarterly, and hourly monetized electric impacts. We leveraged the PSEG Long Island TRM algorithms because the TRM was recently “electrified” through a collaborative stakeholder process to include the impacts associated with electrification, such as changes in electricity and fuel consumption from fuel-switching, along with energy efficiency savings (Ketchman, Fritz-Mauer, and Montijo 2022). We referenced several other TRMs and policy manuals to assist with developing generalized values for the rest of the inputs, including incremental costs, measure lives, line losses, and discount rates.

Table 1. Assumptions used in BCA modelling

Input	Value	Source [A]
Electric Energy Savings	See ccASHP – WH algorithm	PSEG Long Island TRM
Electric Avoided Costs	See study	2021 Avoided Energy Supply Costs (AESC) in New England
Electric Load Shapes	See study	Massachusetts Residential Baseline study [B]
Real Discount Rate	2.90%	Massachusetts, California, Illinois, and New York Policy.
Line Losses	10%	New York, Illinois, and California TRMs
Measure Life	15 years	New York, Massachusetts, and Illinois TRMs

[A] See References section for specifics.

[B] Available at https://ma-eeac.org/wp-content/uploads/RES-1-Residential-Baseline-Study-Comprehensive-Report-2019-04-30.pdf

The purpose of this paper is to (1) highlight the fact that using annual, quarterly, or hourly avoided costs results in tangible differences to BCR results, and (2) categorizing added electric consumption as costs or negative benefits results in tangible differences to BCR results. As such, it was not a goal of this paper to produce jurisdictionally accurate BCR results, and the results should not be interpreted in this manner. With that in mind, we explored three types of heat pump installation scenarios, presented in the sections that follow:

- End of life replacement of existing inefficient heat pump with an efficient heat pump.
- End of life replacement of existing gas furnace (with existing CAC) with efficient heat pump.
- End of life replacement of existing gas furnace (with no existing CAC) with efficient heat pump.

Existing Temporal Distortions

Heating penalties reflect the increased heating loads that result from the installation of efficient equipment, such as LED lighting or ENERGY STAR® refrigerators, due to reductions in waste heat.[1] The magnitude of these negative savings is small enough that treating these savings as negative benefits rather than costs is not likely to have a material impact on the cost-effectiveness results for a program or portfolio. Heating electrification, however, results in large changes in the consumption of electricity and other fuels. The electric heating load of a building can change from zero to full heating load. Additionally, because heating electrification programs focus on high-efficiency heat pumps, cooling loads can also be increased as these systems also provide air conditioning to homes that previously may not have had central air conditioning (NESP 2020).[2]

CHP projects utilize waste heat from on-site fossil fuel electricity generation to provide heating or steam loads, resulting in increased fossil fuel consumption and reduced electricity consumption from the grid. Although CHP projects exhibit large impacts on fuel usage, these impacts are likely to be consistent throughout the year. Conversely, the impacts of heating electrification are disproportionately concentrated in particular times of the day/year. In many jurisdictions, energy efficiency cost-

[1] The ENERGY STAR® name and mark are registered trademarks owned by the US EPA.

[2] Some proportion of participants likely would have installed CAC units had they not installed program-incentivized heat pumps, and this is taken into account by assuming a baseline efficiency CAC unit in savings calculations.

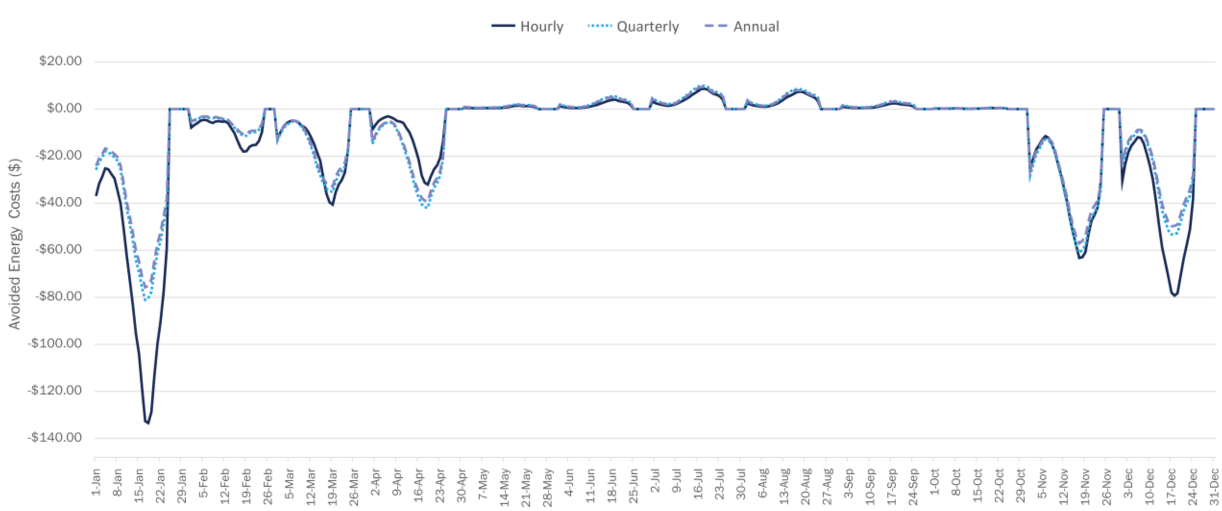
effectiveness analysis is based on average annual avoided costs, which may be sufficient when analyzing the impacts of a CHP or traditional energy efficiency project, but this approach results in a higher distortion of benefits for heating electrification projects when compared to results using quarterly or hourly avoided costs. As illustrated in Table 2, the true cost-effectiveness of electrification technologies cannot be accurately assessed without the use of temporally granular avoided costs. Our analysis found that using hourly avoided costs resulted in a 34% difference in energy benefits compared to using annualized avoided costs, when considering the replacement of a natural gas furnace and CAC with an efficient heat pump.

Table 2. BCA distortions associated with annualized savings and avoided cost values

Avoided cost type	Percent change of NPV of benefits (vs annual)		
	Inefficient heat pump to efficient heat pump	Natural gas furnace and existing CAC to efficient heat pump	Natural gas furnace and no CAC to efficient heat pump
Hourly	115%	134%	117%
Quarterly	115%	107%	107%

Figure 2 provides a visual depiction of the discrepancies introduced by using hourly or quarterly avoided costs versus annual avoided costs. The figure shows the total NPV of monetized energy impacts by day of the year for a replacement of a natural gas furnace and existing CAC with an efficient heat pump when using hourly, quarterly, and annual avoided costs. The largest discrepancies occur during the heating season.

Figure 2. BCA distortions for natural gas furnace and existing CAC to efficient heat pump



Existing Valuation Distortions

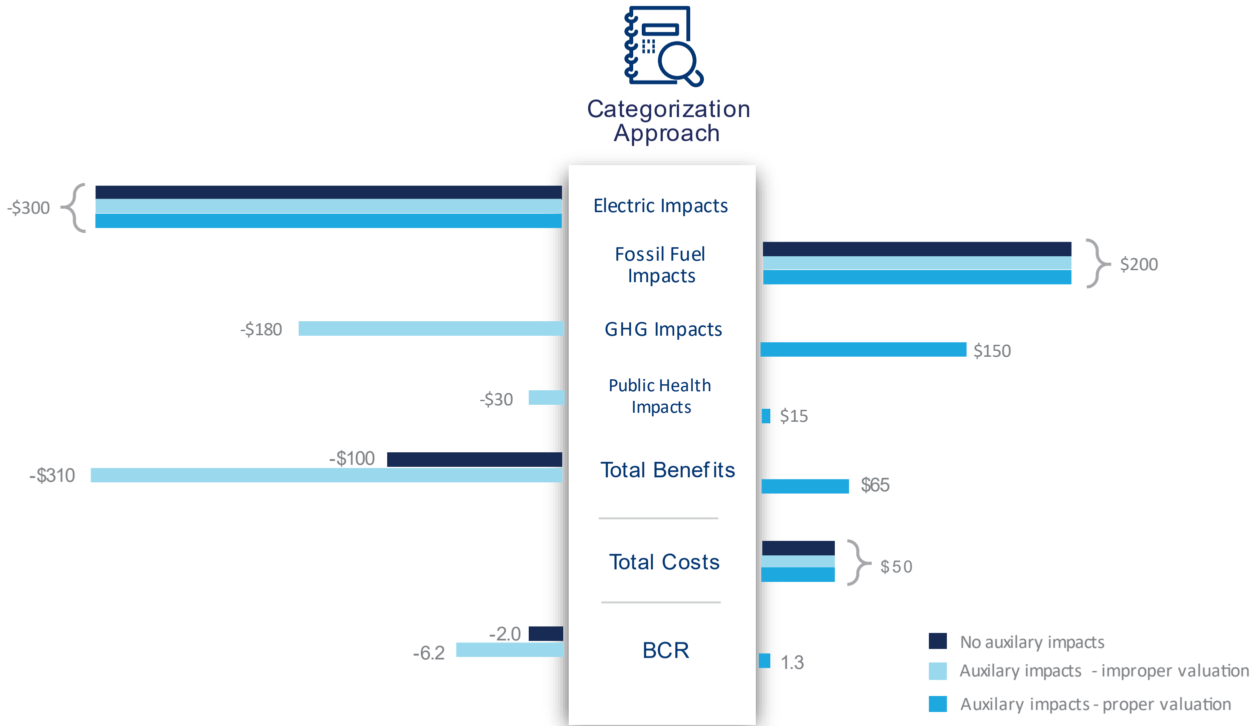
Further adding to this distortion is the fact that many of the auxiliary benefits associated with electrification are not included in cost-effectiveness analyses or not included in a manner conducive to evaluating heating electrification programs. Heating electrification measures can produce other non-energy impacts such as public health impacts (e.g., reduced medical visits for respiratory illness caused by particulate matter emissions), improved household comfort, carbon emissions reductions (i.e., societal cost of carbon), the enablement of “internet-of-things” capabilities like demand response, etc. The omission of these impacts can result in the negative electric savings from electrification having a disproportionate impact on benefit-cost results.

In other jurisdictions where these auxiliary benefits are included in cost-effectiveness analysis, the way they are incorporated into the analysis can be problematic. Mechanically, these benefits may be defined on a per kilowatt-hour basis, leading to uneven inclusion of auxiliary benefits when evaluating a heating electrification project. In electrification scenarios, where electric savings are negative, all kilowatt-hour-based value streams also become negative. Under traditional energy efficiency circumstances, valuing auxiliary benefits solely on a dollar per kilowatt-hour basis may not present issues. However, the relative lack of similar monetized value streams for fossil fuel savings results in an imbalance in the costs and benefits included in the analysis, which is accentuated under electrification scenarios. It is critical that, where appropriate, each value stream included in a cost-effectiveness analysis can be monetized based on each type of potential fuel savings.

In many cases, negative benefits also likely point to an issue with proper savings valuation (e.g., not accounting for all the benefits produced by electrification) as opposed to issues with the cost-effectiveness analysis itself. Program managers and regulators look to BCRs as one point of evidence in determining optimal program deployment, and ensuring costs and benefits are treated equitably across different DER applications will support better decision-making. Further, the primary impetus for electrification programs is generally to reduce greenhouse gas emissions and produce other societal benefits. Although electrification presents the potential to increase peak demand, the average marginal increase in carbon emissions to generate a BTU from the electric grid is lower than the marginal rate of direct combustion of fossil fuels, in most jurisdictions.

Consider a scenario where a jurisdiction includes electric impacts, other fuel impacts, and societal benefits (e.g., GHG savings and public health benefits) in their cost-effectiveness test. A fictional electrification program that costs $50 to implement, increases electricity usage by $300, and saves $200 in fossil fuel impacts, could have drastically different BCRs depending on the manner of accounting for the auxiliary impacts. In the examples in Figure 3, the program produces $330 in GHG impacts from fossil fuel savings and -$180 in GHG impacts from added electricity consumption, as well as $45 in public health impacts from fossil fuel savings and -$30 in public health impacts from increased electricity consumption. The scenario in the first row illustrates the BCR results when auxiliary benefits are not accounted for, the second illustrates the results when auxiliary impacts are only valued on a per kilowatt-hour basis, and the third illustrates the results when auxiliary impacts are valued for all the fuels that are impacted by the program. These scenarios result in BCRs of -2.0, -6.2, and 1.3, respectively (Figure 3). Electrification is critical to decarbonization, and these benefits should be accounted for in BCRs. If a jurisdiction moves to implement electrification programs without updating their cost-effectiveness protocols, benefits will be understated, and possibly even negative.

Figure 3. BCA distortions associated with auxiliary impacts



What are the right costs?

In energy efficiency BCA, negative savings are translated into benefits using the same assumptions as positive savings, namely the avoided cost of energy and capacity values calculated through integrated resource planning exercises or standalone avoided cost studies. Given that any expected increase in energy consumption from traditional energy efficiency are relatively small, taking a marginal cost approach to valuing these savings makes sense. However, heating electrification programs have the potential to impact the electrical grid and utility expenditures in a significant manner. If the decision is made to categorize increased electric consumption as costs, considerations need to be given as to whether estimated avoided electric costs are an appropriate way to monetize these impacts, or if actual costs should be used, as they are in the case of program implementation and administration costs. There are advantages and disadvantages to each approach.

Avoided costs are theoretical values meant to reflect how much it would have cost a utility to procure a kilowatt-hour that is saved through energy efficiency. The costs are based on marginal cost of service studies that can be outdated and simplified but provide a theoretical value for the marginal cost of (or benefit of conserving) a single kilowatt-hour. However, when analyzing a heating electrification program, we flip this paradigm, and the kWh *does* need to be procured. Utilities may be inclined to think about these costs (e.g., transmission and distribution system upgrades) as real costs when they are the drivers of significant actual investments.

Applying the same approach when calculating the benefit of saving a kilowatt-hour and the cost of procuring a kilowatt-hour helps to maintain consistency in the analysis and is a theoretically valid approach. It also ensures that electrification is monetized and analyzed consistent with other energy efficiency resources. Additionally, as previously stated, the cost per kilowatt-hour avoided cost values are theoretical, counterfactual values. Just as saving a single kilowatt-hour may not actually save any money in terms of procuring additional energy, adding a kilowatt-hour of consumption may not actually result in additional expenses to procure energy. Theoretically, the true implementation cost of an electrification program is the difference in energy and system upgrade costs between (1) actual utility expenditures and (2) a counterfactual scenario where, *ceteris paribus*, we remove the program.

Depending on the magnitude and location of the added electric load, however, electrification can result in real costs, such as infrastructure investments (e.g., transformers), and at scale, could result in a need to procure additional generation. Incorporating the real costs of these investments may produce more useful and actionable cost-effectiveness results for utility staff outside of energy efficiency, such as distribution planners. Theoretical counterfactual values may seem consistent and appropriate to evaluators and utility energy efficiency staff, but this may be at odds with the broader perspective of other utility staff who might ask *"How could a program that actually resulted in $4 million in infrastructure upgrades only include $1 million in costs in the cost-effectiveness analysis?"* Notably, evaluators typically do not have access to this type of data, such as capacity constrained infrastructure, that would help identify when and where costs from heating electrification programs may occur.

As a point of comparison, we reviewed how cost-effectiveness of transportation electrification has been conducted throughout the country as it relates to (1) categorizing increased consumption as a negative benefit or cost, and (2) the application of avoided costs or real costs when categorizing increased load as a cost. We consistently found that those conducting the analyses categorized the impacts from added load as costs and that those costs were monetized using avoided energy cost values (E3 2020). While this can help inform decision-making on how to treat increased load from electrification in cost-effectiveness analysis, it is important to note that transportation electrification programs are often funded and administered separately from energy efficiency programs. This is important for two reasons:

- Transportation electrification programs do not need to be included in a cost-effectiveness model that also analyzes a portfolio of energy efficiency programs. It is easier to create a separate, transportation electrification-specific cost-effectiveness tool, thus avoiding the need to overhaul the legacy programming of an existing energy efficiency cost-effectiveness tool.
- Transportation electrification is not considered energy efficiency. As such, there is not necessarily a need to maintain alignment with energy efficiency cost-effectiveness analysis. Since heating electrification measures and programs are typically part of a larger energy efficiency portfolio, and most jurisdictions explore cost-effectiveness of individual programs as well as the overall portfolio, it is important that electrification programs can be analyzed in the same tool and under the same format as the rest of the programs in a portfolio.

Conclusion

The nuances of the technical distortions presented by heating electrification programs necessitate clearly defined policy for calculating the cost-effectiveness of these programs. In many jurisdictions, the policy framework that is in place is not sufficient to ensure all parties conduct and interpret cost-effectiveness analyses of heating electrification programs the same way. These frameworks need to be updated where gaps exist to define where and how negative savings should be categorized. Additionally, implementers, evaluators, and regulators should revisit the benefit and cost streams currently included in cost-effectiveness analysis to ensure all the benefits and costs associated with electrification that can be monetized, are accounted for appropriately. We must ensure that these costs and benefits are not just valued on a per kilowatt-hour basis, but also on a per therm or MMBtu basis, where applicable. Finally, implementers, evaluators, and regulators should investigate the feasibility of developing more granular avoided costs and savings values and/or document the risks of continuing to apply annualized values.

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