Modeling Wisconsin Energy Management Program Alternatives: Hourly Scenario Analysis for Efficiency, Electrification, and Emission Reduction

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ABSTRACT

Energy efficiency programs are increasingly expected to do more than just reduce overall energy consumption, often balancing program budgets with competing objectives including peak demand, electrification, and emissions. Cadmus developed a framework to assess varying program objectives using an approach that combines a bottom-up hourly end-use forecast, flexible peak demand analysis, and utility-specific marginal emissions accounting. This paper presents this methodology and its application to a planning study that evaluated future portfolio options in Wisconsin under realistic constraints on program design and adoption, using scenarios focused on baseline performance, summer peak, load shifting, electrification, and cost-effectiveness.

This case study's results show that portfolios optimized for cost-effectiveness and emissions reduction deliver the strongest near-term performance across multiple metrics, while electrification-focused strategies primarily shift load, often increasing peak demand and yielding limited emissions benefits under expected future grid conditions. Across the five scenarios examined, portfolio outcomes were driven less by fuel switching alone and more by the interactions among measure economics, adoption behavior, and the timing of energy impacts.

This case study demonstrates the increased accuracy of hourly analysis when comparing competing objectives and identifying high-impact measures and end uses, especially for emissions and capacity planning. The outcomes of this approach also highlight the importance of aligning program design with measure economics, customer adoption behavior, and system conditions, and evaluating multiple metrics driven by varied, and often competing, goals. This methodology provides a scalable, transparent, and transferable approach to support planning for policy-relevant energy management programs in increasingly complex energy systems.

Introduction

As electric grids decarbonize and building technologies evolve, the impacts of energy efficiency and electrification are increasingly dependent on when and where energy is consumed or saved—not just how much is consumed or saved overall. Temporal dynamics, including hourly load variation, shifting peak demand periods, and time-dependent emissions intensity, play a critical role in determining the system-level impacts of energy efficiency, electrification, and other load management measures. As a result, traditional planning approaches based on annual savings estimates are no longer sufficient for capturing the full range of impacts associated with modern energy management programs.

This paper discusses an approach to program planning that emphasizes flexible scenario curation and hourly modeling and details the modeling framework and technological approaches used to implement it. It also presents a case study that applied this modeling framework to a planning study for Focus on Energy in Wisconsin with different portfolio scenarios to better understand the impacts of portfolio goals on energy savings and emissions reduction.

Need for Program-Aligned Planning

Conventional energy efficiency potential studies typically quantify technical, economic, and market adoption savings potential using aggregated annual metrics (ACEEE 2026). These approaches have long served as a foundation for setting savings targets, informing policy, and estimating program impacts (EPA 2007). However, they often optimize for a single objective, such as total energy savings, and rely on generalized representations of system conditions. As a result, these approaches may not capture key outcomes that are increasingly important in modern grid contexts, including impacts on electric and gas demand, hourly variations in grid emissions, and the interactions between fuels and technologies.

In addition, traditional potential study methods frequently abstract away real-world constraints, such as customer adoption behavior, program budgets, and incremental evolution of program portfolios over time. Measure-based savings calculations commonly used in potential analyses rely on assumptions that can introduce uncertainty and variability in reported impacts (Orvis, Aggarwal, and O'Boyle 2016). These limitations reduce the effectiveness of traditional approaches for informing program design in an increasingly complex energy system.

At the same time, accurately evaluating lifetime emissions for an evolving, increasingly dynamic grid requires increased resolution. Average emissions factors commonly used in potential studies do not accurately reflect the real-world consequences of changes in electricity demand. Instead, marginal emissions factors, particularly when applied at an hourly resolution, are better suited to capturing the emissions impacts of energy efficiency, electrification, and peak demand reduction measures that vary by time of day and season (WattTime 2024). This further underscores the need for analytical frameworks that account for both the magnitude and timing of energy impacts.

This paper addresses these challenges by introducing an integrated planning model framework that combines hourly end-use modeling with realistic program design constraints and portfolio-based scenario analysis. The framework enables concurrent evaluation of multiple objectives, including energy savings, emissions reduction, peak demand reduction, electrification, and cost-effectiveness, while reflecting practical considerations, such as measure availability, customer adoption behavior, and program budgets.

Cadmus applied this framework to a planning study in Wisconsin and presents the results as a case study of this modeling approach. This study evaluated alternative portfolio strategies under a consistent budget and implementation structure and the results demonstrate that portfolio design strongly influences trade-offs between objectives: cost-effective and emissions-focused portfolios produced the most robust overall performance, while electrification-focused strategies primarily shifted load and increased peak demand. At the same time, optimizing for any focus area needs to be balanced with maintaining a diverse set of offerings to ensure program engagement and measure adoption by a diverse range of energy consumers. These findings demonstrate that integrated, temporally resolved planning is essential for aligning program options with policy goals.

Focus on Energy

Wisconsin Focus on Energy delivers programs across electric and natural gas utilities under a unified regulatory structure that mandates achieving cost-effective energy savings, addressing system capacity needs, and serving diverse customer segments. Focus on Energy operates on a four-year planning cycle-with program priorities, budgets, and savings targets established through a stakeholder-driven process overseen by the Public Service Commission of Wisconsin (Commission). To inform development of the next planning cycle, the Commission contracted Cadmus to evaluate the impacts and trade-offs associated with alternative program design strategies. The resulting Focus on Energy planning study (Bettine et al. 2025) assessed how different portfolio objectives, including cost-effectiveness, emissions reduction, peak demand reduction, and building electrification, affect program performance under realistic implementation conditions.

While Focus on Energy has capacity-related obligations, it does not administer demand response programs, which constrained the set of available strategies for managing peak demand and informed the scope of Cadmus' planning study. Additionally, Focus on Energy generally does not provide incentives to reduce consumption of alternative fuels, such as propane and fuel oil.

Several characteristics of Wisconsin's energy system make adopting a high-resolution analytical approach particularly important. First, the statewide program structure combines electric and natural gas efficiency within a single portfolio, requiring careful consideration of interactions between fuels. Second, the region's relatively high grid emissions intensity, particularly during winter months, affects the emissions outcomes of electrification strategies. Third, Focus on Energy manages a portfolio of programs that cut across multiple utilities, including some with significantly different electric generation profiles. Finally, strong seasonal variation in both load and emissions, driven by significant heating demand, introduces additional complexity to evaluating measure performance. Together, these factors challenge conventional assumptions about the benefits of electrification and underscore the importance of evaluating both the magnitude and timing of energy impacts.

Within this context, the Focus on Energy planning study evaluated energy efficiency and building electrification programs across Wisconsin's residential, commercial, and industrial sectors. The analysis included limited load-shifting technologies but did not explicitly model full-scale demand response programs, reflecting programmatic constraints. The study incorporated the industrial sector's potential, largely driven by custom projects, through a combination of stakeholder input, historical participation data, and projected load growth.

To evaluate trade-offs across program strategies, the study simulated hourly energy use and associated emissions over a 12-year planning horizon from 2027 through 2038, spanning three quadrennial cycles. The methodology integrated a bottom-up hourly end-use forecast with analyses of peak demand-based peak period definitions specific to Focus on Energy (shown in Table 1), marginal emissions factors specific to each utility, cost-effectiveness screening, and technology adoption modeling informed by primary research on customer decision-making and payback sensitivity. To ensure comparability with existing program performance, Cadmus calibrated the baseline scenario to reflect current actual program participation and cost-effectiveness using Wisconsin's modified TRC (mTRC) test (Fontaine 2019).

Table 1. Focus on Energy Peak Period Definitions

Peak Period	Peak Period Definition
Summer PM Peak	Months: June, July, August, September Days: Weekdays excluding holidays Hours: 2 p.m. to 5:59 p.m.
Winter AM and PM Peak	Months: December, January, February Days: Weekdays excluding holidays Hours: 8 a.m. to 11:59 a.m. and 5 p.m. to 8:59 p.m., respectively

By combining granular hourly modeling with realistic program design scenarios, the Focus on Energy planning study provides new insights into how timing, technology interactions, and implementation constraints shape the outcomes of energy efficiency and electrification programs. These insights support more informed and transparent planning processes in Wisconsin (Public Service Commission of Wisconsin 2026) and offer a replicable framework for other jurisdictions facing similar challenges.

Methodology

Modeling Platform

To account for multiple, sometimes competing policy objectives, program portfolios must be evaluated across several dimensions simultaneously. Core metrics for many planning studies, including this case study, include energy consumption reduction, peak demand impacts, emissions reduction, and cost-effectiveness. Critically, emissions, peak demand impacts, and costs can vary significantly by hour, meaning that annualized metrics obscure important temporal dynamics. To address this, Cadmus developed an hourly modeling framework to evaluate measure impacts across all hours of all years in a study horizon, capturing seasonal and diurnal variation in emissions and load, and integrating both electric and gas impacts within a unified structure. While hourly modeling is not new, this modeling framework extends prior approaches by evaluating all measure permutations across multiple years at hourly resolution, enabling a more precise and policy-relevant assessment of program impacts.

Planning studies require running a model many times to evaluate and compare numerous scenarios, iterate on inputs, and refine assumptions and modeling techniques. The result is an unwieldy amount of data. For the Wisconsin case study, the commercial sector alone comprised approximately 1.2 million permutations (6 electric utilities × 4 gas utilities × 2 equity populations × 4 ownership categories × 3 segments × 2 building vintages × ~1,050 measure combinations). Expanding to annual estimates for a 12-year study resulted in ~14.4 million rows, and multiplied by 8,760 hours per year yielded 126 billion rows of data for each hourly table at full resolution. Each model run requires dozens of input and intermediate calculation tables and several hourly result tables, totaling many hundreds of billions of rows of data for a single scenario run—far more than a conventional desktop computer can realistically handle.

Previous models have often relied on Excel, which is limited to about 1 million rows of data per sheet, or on local R and Python scripts. To support these massive data volumes, the team implemented the model using Databricks, a distributed computing and data engineering platform based on the open-source Apache Spark framework (Zaharia et al. 2016). Leveraging the Spark architecture on an accessible cloud computing platform enables compute clusters that can scale nearly infinitely, holding billions of model permutations in memory simultaneously. A clear, consistent data model with managed structured data tables, model run tracking, and full traceability of inputs for every model result helps ensure confidence in results. Cloud storage of data and results also streamlines their review, quality control, and interpretation. Subject-matter experts and stakeholders can quickly review each model run in interactive real-time dashboards from a web browser on any device without downloading or installing specialized software or waiting for an analyst to upload results to a shared location. This enables faster iteration, allowing more scenario variations to be explored and optimized in a given project timeline and budget.

Cadmus developed a next-generation end-use simulation platform that manages inputs (customers, market data, end uses, measures, and hourly load shapes) in a centralized cloud data warehouse and executes scalable, distributed computations capable of evaluating billions of permutations across scenarios. Built-in capabilities include baseline calibration to utility sales, dynamic adjustments to energy intensities, weather patterns, equipment saturations, fuel and efficiency shares, stock turnover driven by effective useful life, discrete modeling of equipment standards, behavioral adoption modeling with incentives/payback, integrated treatment of fuel switching and efficiency, weather-sensitive hourly load adjustments, and integration with a cost-effectiveness engine that accepts full 8,760-hour avoided cost profiles.

Modeling Approach

Applying this model to a study like the Focus on Energy planning study starts with an initial end-use forecast to predict end-use energy consumption across all sectors, building types, income levels, utility territories, and other population factors. The end-use forecast provides the comparison point for energy efficiency potential, peak demand, and emissions impacts.

First, an annual estimate of energy consumption is created from a detailed characterization of the building stock across sectors (residential, commercial, industrial, and agricultural). This baseline consumption estimate incorporates customer counts, equipment saturations, end-use fuel shares, building characteristics (e.g., floor area), and equipment unit energy consumption. Bottom-up annual totals are then calibrated to base-year utility-reported annual sales to ensure consistency with observed system conditions.

These input values, which use a standard format, are tailored to each study. Cadmus developed a behavioral model using primary customer data and research specifically conducted for the Wisconsin case study to forecast accounts for anticipated changes in equipment stock over the study's time horizon as new construction and replacements move toward different technologies and efficiency levels. Cadmus sourced other input assumptions, such as equipment saturations, calibration values, and measure characteristics, from a variety of sources, including utility-provided account and load data; state-specific field studies like the Wisconsin Residential New Construction Baseline Study (Cofer 2022) and other statewide site visit data; national studies, such as the Commercial, Residential, and Manufacturing Energy Consumption Surveys (EIA 2026); and selected relevant data from regional studies in other jurisdictions. Studies elsewhere would use similar reference data and incorporate available regional and utility-specific inputs and assumptions.

To develop the hourly end-use forecast, Cadmus assigned a specific hourly profile to each unique combination of the sector, building type, region, and end use. The normalized load profile is then multiplied by the annual energy load for that end use. In general, load shapes for this methodology are often sourced from metering studies, building simulations, and engineering analysis. With recent research by the National Laboratory of the Rockies (NLR 2019) and its ResStock and ComStock libraries, a vast set of load shapes for specific regions of the United States is now available. Load profiles are typically provided initially with only a single year of data and then adjusted for each study year to account for shifting holidays, weekdays, and weekends, as these impact many hourly uses. This flexible approach allows for the selection of load shapes for specific geographies of interest and available regional datasets.

After establishing the baseline forecast, the model estimates potential for various scenarios by layering on energy efficiency and electrification measures. Baseline customer counts are retained but applied to different assumptions for end-use unit energy consumption, equipment shares, efficiency levels, end-use fuel types, and savings from specific energy efficiency retrofit measures that reduce consumption without replacing end-use equipment. A separate load profile is assigned to each savings measure, and an hourly savings forecast is developed for the study horizon in a manner similar to the baseline forecast. The resulting adjusted forecast for each scenario is calculated by subtracting its savings from the baseline forecast.

Electrification scenarios are modeled by replacing specific fossil fuel end-use equipment with electric end-use equipment, requiring additional modeling logic to account for fuel conversions. This includes accounting for downstream impacts of energy efficiency, such as building shell retrofits, shifting from gas savings to electric savings when electrification occurs. This level of granularity exceeds standard practice in energy efficiency potential studies. Energy savings are typically normalized and reported in BBtu rather than fuel-specific metrics, such as kilowatt-hours or therms, to make electric and gas impacts comparable.

The model explicitly accounts for interactions between electrification and traditional energy efficiency. This integrated approach highlights trade-offs that are often overlooked in siloed analyses. The analysis incorporates key system-level factors, including conversion efficiency of electricity generation (e.g., ~40% for single-cycle and ~60% for combined-cycle natural gas plants), anticipated changes in grid composition over time, and seasonal alignment between renewable generation and heating demand. Together, these factors are critical for accurately assessing electrification impacts.

The baseline end-use forecast can be compared to each potential scenario at an annual or hourly level and queried by dimensional characteristics and specific years and hours to assess and compare scenarios, build optimized program offerings, and assess demand impacts for any peak definition. For the Wisconsin case study, Cadmus evaluated five scenarios and ran dozens of model iterations for each scenario to fine-tune input assumptions and build optimized combinations of measures. These scenarios are detailed in the results section below. Table 2 provides examples of measure categories selected from each sector of the end-use forecast and energy potential estimates for the Wisconsin study.

Table 2**.** Examples of measure categories by sector

Residential	Commercial	Industrial	Agricultural
Weatherization projects	Advanced rooftop unit controller	Process heat recovery	Grain dryers
Window insulation	HVAC commissioning	New construction design	Process heat improvements
Water heat	Direct digital control system	Custom process improvements	High-efficiency gas water heaters
Sill box insulation	Lighting controls	Custom boiler projects	Ventilation/circulation fan VFDs
Gas furnaces	Automated ventilation CO_2 sensors	Boiler heat recovery	High-volume low-speed fans
Energy recovery ventilators	HVAC pump and fan VFDs	Boiler management	Irrigation improvements
Door insulation	Boilers	Lime kiln improvements	Lighting
Heat pump water heaters	Cooking equipment	HVAC controls	Dairy heat exchangers

Electric Generation Emissions

The model calculates emissions impacts from direct combustion and from electric generation using hourly profiles and can ingest any emissions forecast source, with different values for each sector, region, and utility within the study area, for each hour of each year forecasted in the study. For studies in which detailed region-specific emissions information is not available, resources such as the NREL Cambium model can be used to establish long-run marginal emissions profiles for a selected year range and region.

The Wisconsin case study used generation profiles developed for each major Wisconsin utility using a stakeholder-approved region-specific methodology (Bettine et al. 2025). This methodology leveraged annual electric generation asset shares and associated emissions factors from Wisconsin's Strategic Energy Assessment (Public Service Commission of Wisconsin 2024) for 2024 through 2030 for baseload and non-baseload generation. To develop hourly emissions intensities, Cadmus assumed that baseload generation emissions were evenly distributed across the year, while emissions for non-baseload resources were distributed hourly using dimensionless profiles developed from historical EIA Grid Monitor data (EIA 2025). The case study assumed that emissions factors remain constant at 2030 levels in subsequent years.

Case Study Design

The Focus on Energy planning study modeled the impacts of six alternative future program portfolios, each with a distinct policy focus. To make these scenarios realistic, the study first developed a baseline program portfolio, which it based on historical measure-level adoption trends and calibrated to recent program performance, including energy savings and cost-effectiveness. Cadmus also conducted a comprehensive gap analysis between the previous potential study results and historical program participation to understand which past assumptions about measure uptake to adjust to produce future participation estimates that reflect actual adoption trends. To develop a representative baseline scenario, Cadmus then designed a portfolio for the study that included programs, associated measures, and incentive and non-incentive administrative and technical support budgets. To estimate long-term uptake of currently offered and new measures, the study leveraged an adoption model that combined each measure's payback period with customer segment-specific adoption thresholds. To develop these adoption thresholds, Cadmus conducted primary research, including hundreds of online surveys with residential and commercial energy consumers and in-depth interviews with large industrial customers.

The baseline program scenario included incentive levels and budget distributions based on current Focus on Energy patterns. It also included measures currently offered by Focus on Energy and additional measures likely to be included in the next iteration of program offerings (identified by Cadmus in consultation with stakeholders). While the baseline scenario does not perfectly match the budget, structure, or measure mix of the current offerings, it reflects a reasonable program design that likely approximates the business-as-usual approach.

After designing a baseline scenario, Cadmus modified the baseline assumptions for each additional scenario by disabling measures that did not contribute to meeting the scenario's priorities and adjusting incentives for measures aligned with those priorities to boost the estimated adoption rates for those measures. The study maintained consistent budgets for the overall portfolio and each program across scenarios. Table 3 shows the design for each scenario (Bettine et al. 2025).

Table 3. Focus on Energy Planning Study Scenario Design

Scenario	Description	Scenario Details
0	Baseline	• Aligns current program design with previous offering iterations as much as feasible • Distribution of budget based on 2021–2023 budget allocations • Incentives aligned with 2025 offerings
1	Emissions Focused	• Removes measures with lowest emissions reduction potential within each sector program (excluding New Construction and Solar PV) • Increases incentives for measures with highest emissions reduction potential
2	Summer Electric Peak Focused	• Increases incentives for measures with highest summer peak reduction impacts
3	Summer Electric Peak Focused (with Load Shifting program)	• Increases incentives for measures with highest summer peak reduction impacts • Moves $5 million from non-load-shifting program budgets to load-shifting program budgets in the residential and commercial sectors
4	Electrification Focused	• Adds electrification measures that are not currently offered by Focus on Energy • Increases incentives for existing electrification measures
5	Cost-Effectiveness Focused	• Increases incentives for measures with highest cost-effectiveness from the mTRC perspective • Removes measures with lowest cost-effectiveness from the mTRC perspective

To ensure continuity between the study's potential estimates and program performance, Cadmus estimated measure-specific savings using evaluated program savings whenever possible, rather than unique and new engineering calculations. This approach ensured that savings estimates aligned with observed savings from Focus on Energy programs. The team ran each portfolio prototype through the hourly modeling framework, enabling a detailed assessment of total energy savings, hourly and seasonal emissions impacts, peak demand reductions, and portfolio cost-effectiveness. This approach ensured that scenario comparisons captured both aggregate outcomes and temporal dynamics.

Results and Scenario Insights

Across all scenarios, portfolio design strongly influences trade-offs between energy savings, emissions reductions, peak demand, and cost-effectiveness. To better examine these trade-offs, Cadmus measured and reported energy savings in BBtu to make electricity and gas savings comparable across portfolio scenarios.

Relative to the baseline portfolio, which included 190,300 lifecycle BBtu savings and showed cost-effectiveness under mTRC of 1.5, the emissions-focused and cost-effectiveness-focused scenarios increase lifecycle energy savings by approximately 25% and lifecycle emissions reductions by over 20% while improving cost-effectiveness. In contrast, the electrification-focused scenario produces minimal net gains and increases electric peak demand, reflecting load shifting rather than net savings. These results suggest that near-term performance is driven more by measure economics and adoption than by fuel switching alone (Bettine et al. 2025). Table 4 (Bettine et al. 2025) summarizes metrics across all scenarios in the Wisconsin case study, and Figure 1 summarizes lifecycle energy savings in greater detail across scenarios.

Table 4. Scenario Impacts

Scenario	Lifecycle Energy Savings (BBtu)	Lifecycle Carbon Emissions Savings (million metric tons)	2030 Summer PM Peak Reduction (MW)	Cost-Effectiveness mTRC Ratio	Acquisition Cost ($/MMBtu)
Baseline	190,300	9.9	227	1.5	1.4
Emissions Focused	237,900	12.2	278	1.8	1.2
Summer Peak Demand Focused	215,700	11.2	300	1.8	1.3
Summer Peak Demand Focused with Load Shifting	209,900	11.7	294	1.8	1.3
Electrification Focused	194,700	10.1	211	1.5	1.4
Cost-Effectiveness Focused	234,400	12.1	289	2.2	1.2

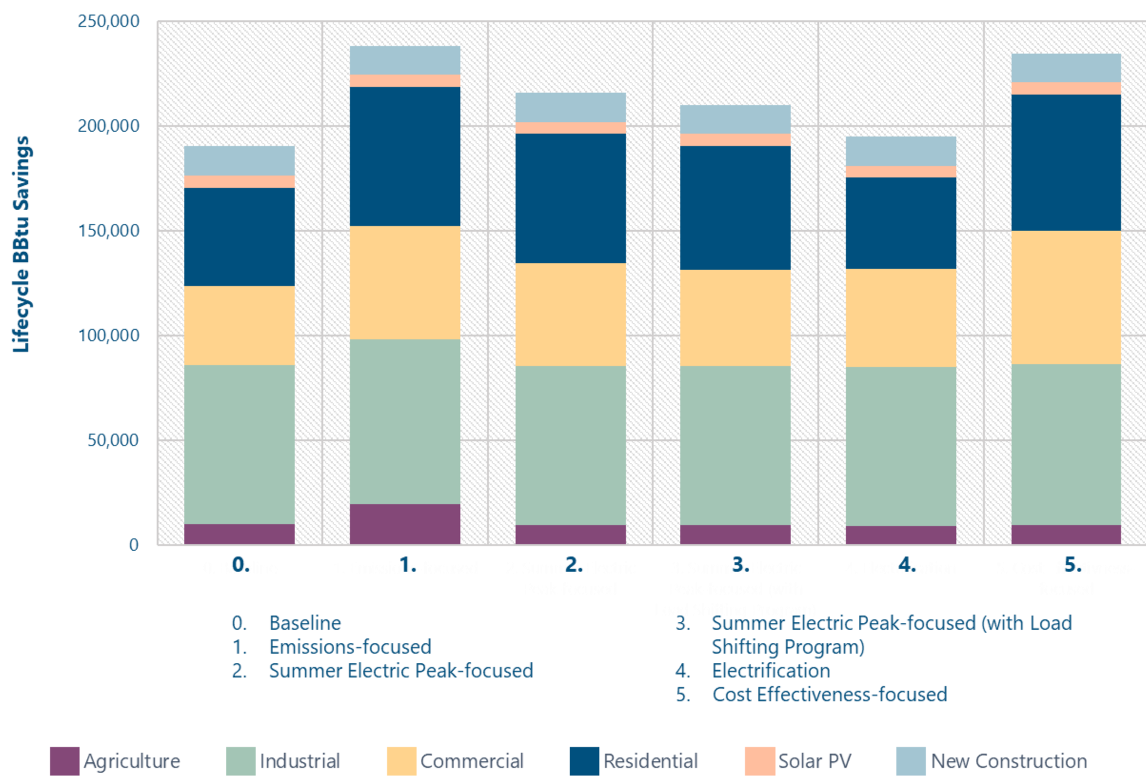

Figure 1. Lifecycle energy savings by scenario (BBtu)

In this case study, the baseline portfolio underperforms all alternatives, achieving the lowest lifecycle energy savings, lifecycle emissions reductions (9.9 Mt CO_2), and peak demand impacts. Both the emissions-focused and cost-effectiveness-focused scenarios deliver comparable improvements. Peak-demand-focused scenarios achieve the largest reductions in summer electric peak demand (~300 MW) but produce smaller gains in energy savings and emissions reductions than emissions-focused and cost-focused scenarios. In contrast, the electrification-focused scenario delivers minimal improvement in total energy savings, limited emissions reductions, and increased electric peak demand.

Energy, Emissions, and Cost Trade-offs

A central finding of the case study is the strong alignment between emissions reduction and cost-effectiveness outcomes. The cost-effectiveness-focused scenario achieves emissions reductions of approximately 12.1 Mt CO_2, which is nearly identical to reductions for the emissions-focused scenario (~12.2 Mt CO_2), while delivering the highest overall cost-effectiveness result of 2.2 from the mTRC perspective.

This result challenges the assumption that emissions reductions require trade-offs with economic efficiency. Instead, measures with a low incremental cost per unit of energy saved enable higher total savings and associated emissions reductions within fixed program budgets. However, both optimization strategies reduce measure diversity by prioritizing high-performing measures and excluding lower-performing options. These excluded measures often serve as entry points for customer participation, which introduces a trade-off between maximizing short-term portfolio metrics and sustaining long-term customer engagement. Since diversifying program offerings also encourages participation from a broader range of customers in energy efficiency programs, it is necessary to maintain sufficiently diverse offerings to meet and maintain utility mandates for customer populations served.

Peak Demand Outcomes

The peak demand outcomes in this case study differ substantially from energy and emissions outcomes, indicating that demand management constitutes a distinct optimization objective. Peak-demand-focused scenarios achieve the largest summer peak reductions (~300 MW), driven primarily by enhanced deployment of established energy efficiency measures targeting cooling loads.

Standalone load-shifting strategies, including battery and thermal storage, provide limited incremental benefit under current program assumptions. While these technologies can reduce demand during short-duration peak periods, their effectiveness diminishes when peak demand is defined across multi-hour time windows. This case study demonstrates that low-cost, widely deployable technologies, such as smart thermostats, can make a more scalable contribution to peak reduction when integrated into broader portfolios.

Electrification Outcomes

The electrification-focused scenario highlights the distinction between fuel switching and overall system performance. While electrification reduces natural gas consumption, it increases electricity demand, resulting in limited net energy and emissions benefits within the study timeframe. Figure 2 illustrates the distribution of energy savings by fuel type. Based on eGRID analysis, Wisconsin's carbon emissions rates are approximately 1,163.6 lbs. CO_2e/MWh. Emissions rates vary widely across the US, ranging from 52.2 to 1,968.9 lbs. CO_2e/MWh (EPA 2023). Performing a similar analysis in other states with lower grid emissions could result in more favorable outcomes for electrification scenarios.

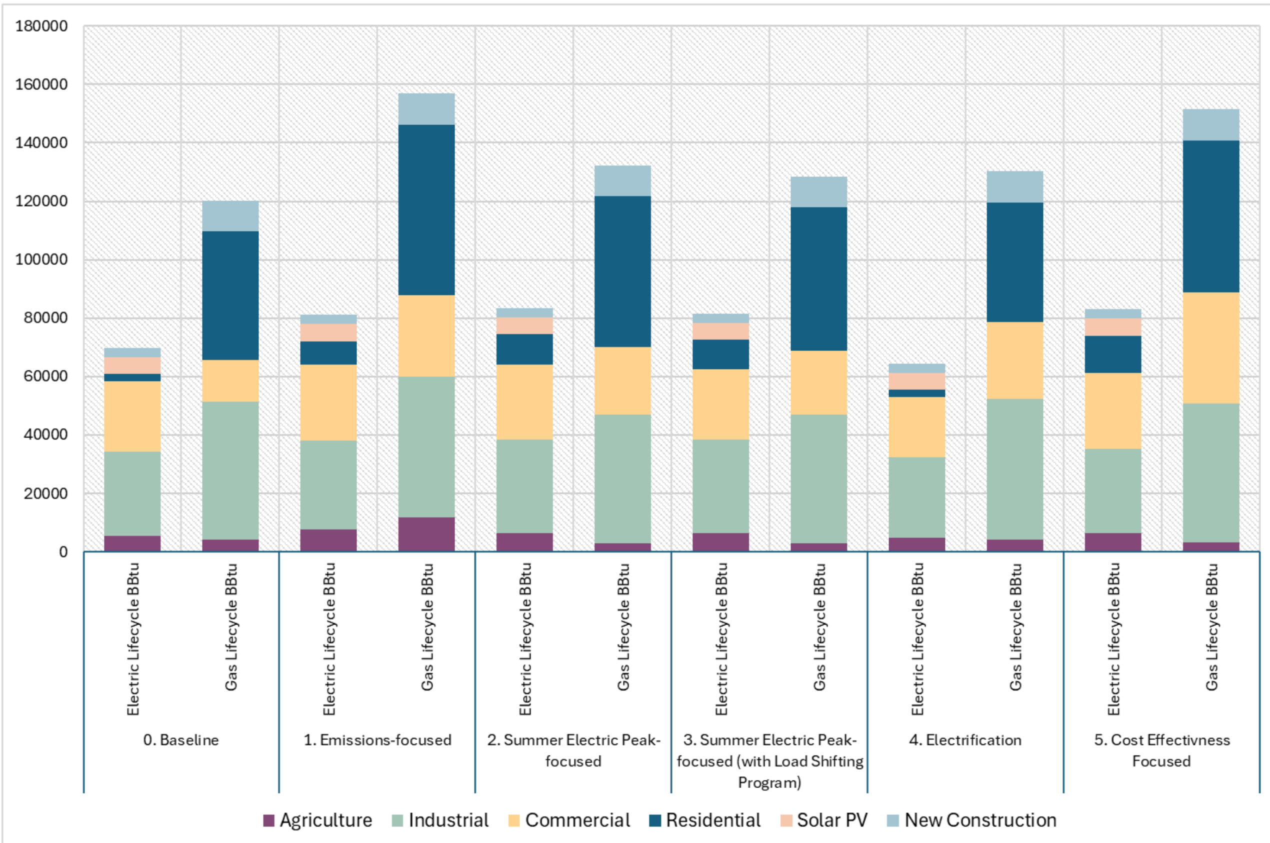

Figure 2. Lifecycle energy savings (BBtu) by fuel type and sector

Three key dynamics explain the performance of the electrification scenario:

1. Fuel shifting dominates total outcomes: Electrification primarily shifts savings from electricity to gas rather than increasing total savings.
2. Electric peak demand increases: Additional electric load, particularly for space heating, increases winter peak demand relative to efficiency-focused scenarios.
3. Adoption and cost barriers limit scale: Higher incentives are required to drive electrification adoption, reducing the budget available for cost-effective efficiency measures and limiting overall program performance.

These results indicate that electrification alone does not maximize near-term program outcomes under current grid conditions and market constraints.

Key Findings

Program outcomes are strongly influenced by the distribution of cost-effective potential across sectors. The industrial sector contributes the largest share of total savings (~40%), followed by the residential (~25%), commercial (~20%), and agricultural (~5%) sectors. The Focus on Energy planning study accounted for savings from the solar and new construction programs separately across all sectors. Industrial measures exhibit consistently high cost-effectiveness, resulting in limited performance gains from scenario optimization. In contrast, residential and commercial sectors contain a broader mix of high- and low-cost measures, making them more sensitive to portfolio design choices. These findings indicate that measure-level economics, rather than sector allocation alone, drive portfolio performance.

Across all scenarios, five key findings emerge:

1. The baseline portfolio underperforms across all evaluated metrics.
2. Emissions-focused and cost-effectiveness-focused scenarios deliver the strongest overall performance of all the scenarios.
3. Electrification primarily shifts energy use and can increase peak demand.
4. Peak demand reduction is only weakly correlated with energy and emissions outcomes.
5. Portfolio performance is driven primarily by measure economics and customer adoption dynamics.

The results of the Focus on Energy planning study highlight the importance of integrated portfolio design that balances multiple objectives. While optimizing for a single objective, such as cost-effectiveness or emissions reduction, can yield strong near-term outcomes, making decisions based on such approaches may reduce program diversity and limit long-term customer engagement.

A hybrid strategy, anchored in cost-effective measures while maintaining a diverse set of program offerings, may provide the most robust pathway for achieving sustained energy savings, emissions reductions, and demand management benefits consistent with program design best practices. Including select measures that drive participation and customer satisfaction will sustain engagement and enhance long-term program success across all metrics.

Study Implications

The Focus on Energy case study demonstrates the value of an integrated hourly modeling approach that accounts for changes to electric and gas loads over all building end uses. This approach allowed Cadmus to identify the impacts of specific measures at specific hours of the year, in terms of peak energy reduction (or, in the case of electrification, increase) and electric generation emissions rates. Identifying the measures with the greatest and least impact on the chosen metrics enabled the design of several alternative scenarios, each of which maximized or minimized the contribution of measures based on their impact. Those scenarios could only be differentiated by using an hourly modeling approach that aligned measure characterization, calibration, and population estimates with real program data and applied compatible scenario constraints on cost-effectiveness and realistic program offerings. The results observed in this case study are regionally specific and would likely look very different in another jurisdiction with different peak periods, emissions factors, measure selections, and program constraints. This type of customized analysis, along with the ability to rapidly iterate on and compare highly granular, carefully tuned program scenarios, enables utilities and efficiency programs to identify where their programs can have the greatest impacts and to evaluate tradeoffs between overall energy demand, emissions, cost-effectiveness, and customers served.

As planning studies move toward incorporating hourly impact analysis, program evaluation methodology and granularity will need to evolve and align with these studies. Over the long term, an integrated approach to program planning, potential analysis, and ongoing evaluation may be the most efficient and accurate way to plan program portfolios.

Study Limitations

This study focused on future possible program offerings and did not consider demand response in its portfolio analysis. Demand response programs, which are designed to reduce peak demand and therefore impact grid emissions and energy use, also benefit from large-scale hourly analysis. Cadmus is currently developing a demand response module for this model platform and will be applying it in other jurisdictions with demand response programs in future studies.

Another limitation of this case study was that it relied on electric generation profiles that are static past 2030, while the lifetime of the measures considered in the study impacts energy consumption well beyond that timeframe. As a result, the emissions reductions, electric savings, or electrification impacts might be substantially different from those projected if the resource mix on the Wisconsin grid were to shift in the long term.

Also, the Focus on Energy planning study did not model the potential emissions or load impacts from converting alternative fuels, such as propane or fuel oil, to electricity, since no programs in the portfolio address these fuel types. However, the hourly energy and emissions impact analysis can be applied to any fuel conversion, and Cadmus has used the same modeling framework to analyze the electrification of delivered fuels in other studies.

Equity Considerations

Income-qualified households (≤80% of the area median income) represent approximately 38% of Wisconsin households but are underrepresented in program participation. The Focus on Energy planning study's program scenarios include a dedicated budget for income-qualified incentives equal to 9% of the total residential budget. While a household can participate in any program, the income-qualified budget constraint likely limits the adoption of energy savings measures by income-qualified households. This finding suggests that Focus on Energy may be able to achieve additional savings in the residential income-qualified sector by increasing the budget dedicated to these households. However, any budget decisions for income-qualified offerings should also consider the implications for overall portfolio cost-effectiveness requirements (Bettine et al. 2025).

Transferability

Cadmus designed the analytical framework used in this case study to be transferable across jurisdictions and applications. Bottom-up end-use forecasting, hourly load modeling, emissions accounting, adoption modeling, and cost-effectiveness screening are useful for utility integrated resource planning, decarbonization planning, and grid load forecasting. This modeling framework is currently being used for regional long-term grid forecasting in Ontario, Canada, and utility load and potential forecasting in Washington state. The framework could also be applied to utility integrated resource planning, where hourly end-use impacts can inform assessments of peak demand, energy growth, avoided system costs, and resource adequacy under changing electrification and load-shape conditions. It could also support decarbonization planning by evaluating how efficiency, electrification, storage, and demand flexibility interact with evolving generation portfolios and hourly emissions patterns.

Cadmus is currently developing additional modules for upcoming studies, including integrating additional jurisdiction-specific cost-effectiveness tests, behind-the-meter solar and storage potential forecasting, demand response potential forecasting, and granular customer-specific industrial forecasting. Each module integrates with the baseline forecast and energy efficiency potential estimates to produce aligned forecasts in a shared data environment.

Conclusion

The increased availability of large-scale distributed computing resources and granular, regionally targeted hourly end-use load profiles across a wide range of measures and building types enables large-scale hourly analysis. This capability supports a wide range of scenarios relevant to forecasting and planning for grid load, energy efficiency, electrification, emissions, and peak demand impacts.

The use of detailed bottom-up hourly end-use forecast scenarios in the Wisconsin case study allowed insight into a range of distinct portfolio scenarios. Across these five scenarios, portfolio outcomes were driven less by fuel switching alone and more by the interactions among measure economics, adoption behavior, and timing of energy impacts. Cost-effectiveness and emissions-focused scenarios delivered the strongest overall near-term performance, with both demonstrating strong overall energy savings, cost-effectiveness, and emissions reductions. In contrast, scenarios focused on peak demand reduction showed some benefits but were constrained by program limitations, while the electrification-focused scenario was constrained by high costs and limitations of fuel switching under current and forecasted statewide grid conditions.

These findings have several important implications for program planning. First, integrated portfolio design rather than single-objective optimization is essential for balancing competing policy goals. Second, hourly resolution is more than an analytical refinement, as this approach allows more accuracy in valuing program impacts, particularly for emissions and capacity planning. Third, maintaining a diverse portfolio of measures may be critical for sustaining long-term customer participation and market transformation.

The case study also points to broader institutional implications. As planning methodologies evolve toward hourly analysis, EM&V practices will need to align to ensure that the measurement of realized impacts is consistent with planning assumptions. Additionally, the scalability and transparency of cloud-based modeling platforms enable more iterative, stakeholder-informed planning processes, supporting better decision-making in conditions of uncertainty.

While these results are specific to Wisconsin's grid characteristics and program constraints, this modeling approach can be extended to other study formats and jurisdictions. Using regionally appropriate portfolio selections, calibration factors, long-term marginal emissions rates, costs, and load profiles may yield substantially different conclusions about the trade-offs between electrification, emissions, and cost-effectiveness.

Ultimately, this work shows that the next evolution of energy planning must move beyond static metrics toward integrated, time-resolved approaches that reflect how energy systems operate. Doing so will enable programs to more effectively achieve emissions reductions, manage peak demand, and deliver cost-effective outcomes to customers navigating an increasingly complex energy landscape.

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