Mind the Gap: Modeling Accelerated Code Adoption

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ABSTRACT

Energy savings is an increasingly consequential factor in utilities' forecasts. Widely-adopted forecasting practices can readily address steady improvements in efficiency baselines, energy codes, and market practices. However, accommodating the major shifts in policy and practice necessary to address climate change is more challenging. Adding to this complexity are the nuances of how changes in load can affect the carbon emissions profile of the electric generation mix. This paper summarizes a recent study in Minnesota commissioned by a utility preparing an integrated resource plan. The team modeled a major shift in commercial energy code mandated by state legislation. The study estimated the savings impact of different accelerated code adoption scenarios for different building types compared to the current trajectory and the legislative goal. Specifically, we found that some building types could come close to or even meet the state's new target for reducing energy use (80 percent reduction in annual net energy consumption for commercial new construction by 2036) while other segments had a large gap between known paths—even when considering electrification—and the state's target. The study modeled code adoption scenarios for five major building types. The four core scenarios included: 1) a baseline scenario of adoption following the state's typical trajectory; 2) an accelerated scenario assuming adoption of each new published edition of ASHRAE 90.1 or a more efficient standard in the year of publication; 3) the accelerated scenario plus installation of solar PV; and 4) the goal scenario modeling the trajectory needed to achieve the legislative target. The team also modeled a fifth scenario that modeled full electrification of the buildings.

Introduction

Xcel Energy has treated energy efficiency as a resource bundle in Minnesota integrated resource plans for a decade by using a measure life weighting calculation to remove the expected effects of efficiency from sales data prior to forecasting future sales. This allows various scenarios to be tested without possible double counting of impacts. However, this method only works when the expected efficiency gains are either occurring through traditional rebate programs or when efficiency follows a relatively predictable trajectory of naturally occurring efficiency that becomes implicit in the econometric modeling outputs.

Adoption of SF 3035 (the 2023-2024 Omnibus Jobs, Economic Development, Labor, and Industry appropriations bill)[1] during the 2023 Minnesota Legislative session significantly shifted the expected pace of commercial energy code adoption. The text of the bill reads:

(e) Beginning in 2024, the commissioner shall act on the new model commercial energy code by adopting each new published edition of ASHRAE 90.1 or a more efficient standard. The commercial energy code in effect in 2036 and thereafter must achieve an 80 percent reduction in annual net energy consumption or greater, using the ASHRAE 90.1-2004 as a baseline. The commissioner shall adopt commercial energy codes from 2024 to 2036 that incrementally move toward achieving the 80 percent reduction in annual net energy consumption.

At the same time, two new programs were introduced in the market aimed at energy code support—an initiative of the Minnesota Efficient Technology Accelerator focused on code advancement and a collaborative energy code compliance program jointly administered by the five largest electric and natural gas investor-owned utilities in Minnesota. Understanding the combined effects of these two efforts drove the question of whether a third way of accounting for code savings needs to be created, beyond econometric modeling and code support program savings.

Xcel Energy contracted with Michaels Energy to investigate the gap that arises when we see codes advance quickly and with much greater effort to ensure compliance than previous modeling would adequately capture. Michaels Energy focused on leveraging a few different practices within the energy efficiency industry, looking at scenario modeling typically conducted for above-code new construction programs as well as the methods used by Pacific Northwest National Laboratory (PNNL) for assessing the efficacy of new energy codes.

Context

In addition to characterizing how the state policy change would affect electric system planning, Xcel Energy was also motivated to better understand how different scenarios would affect its commitment to reducing electric and natural gas emission reductions. Since 2020, Xcel Energy has released and updated high-level plans for the coming 25 years with an objective of achieving net zero emissions for both electricity and natural gas by 2050 (Xcel Energy, 2025). Displacing natural gas use with electricity is a portion of achieving this goal, meaning that whole building modeling becomes even more important to predicting how electric use will be affected over time by the combination of electrification and declining energy use intensity dictated by the energy code. In addition, assessing the cost-effectiveness of various decarbonization strategies becomes a more challenging cross-fuel exercise as higher uptake of non-dispatchable electric generation is enhanced or diminished depending on alignment between when the energy-consuming end uses occur and times that carbon-free generation peaks. This level of analysis is

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[1] 2023 Minnesota Session Laws, Chapter 53, Section 29

something that whole building models can provide, though this specific use case has only recently emerged.

Methods

To estimate the energy consumption of different building code scenarios, Michaels Energy followed a similar approach to that used by PNNL in the Impact of Model Building Energy Codes study (Tyler 2021) illustrated in Figure 1.

Figure 1. Summary of Building Energy Code Savings Estimation

To estimate the difference in energy consumption between different code scenarios, the study team first established the energy use intensity (EUI) of each building type, applied a compliance factor to estimate the savings realized in the field, and multiplied the EUI savings by the new floor space expected to be constructed, resulting in annual and cumulative energy savings. Each of these steps required the study team to develop assumptions based on the best available sources. The methodologies for developing these assumptions are outlined below.

Building Segments

The study team targeted five building segments, plus an "Other" segment, on which to focus. These segments included:
- Office
- High-rise multifamily
- Food service
- Retail
- Education
- Other

The Office segment was an aggregation of both small/medium (under 100,000 SF) and large (≥100,000 SF) buildings. According to Dodge, large office buildings accounted for 88% of 2018

office construction starts in Minnesota (Slipstream 2020). The "Other" segment is based on the weighted average area of the segments under study.

Table 1. 2023 Building Starts (SF) by Building Type (Source: Slipstream 2020)

Building Type	Study Category	2023 Building Starts (SF)	Share of 2023 Building Starts (% SF)
Schools/Educational	Education	1,344,444	6%
Restaurants	Food Service	414,979	2%
Dormitories	High Rise MF	62,592	<1%
Multi-family	High Rise MF	11,126,478	54%
Office and Bank Buildings	Office	820,092	4%
Government Service Buildings	Office	118,847	1%
Stores	Retail	414,979	2%
Warehouses	Other	1,347,271	6%
Parking Garages/Auto Service	Other	2,834,813	14%
Manufacturing	Other	467,286	2%
Hospital and Health Treatment	Other	640,269	3%
Religious Buildings	Other	48,927	<1%
Amusement/Recreational	Other	297,649	1%
Miscellaneous Non-Residential	Other	341,164	2%
Hotels and Motels	Other	485,735	2%
Total		**20,765,526**	**100%**

Based on New Construction Commercial Square Footage Data from Minnesota Commercial Energy Baseline and Market Characterization Study.

As shown in Table 1, the high-rise multifamily building segment accounted for 54% of 2023 new construction commercial square footage, while the other segments made up between 2% and 6% of building starts. The Other segment represented 31% of the total (Slipstream 2020).

New Building Square Footage

To align results of this analysis with past studies, the study team started with the same assumptions about new building square footage as those used in the Minnesota Code Program Development Report (TRC 2022). The study estimated the square footage of Minnesota commercial new construction building starts based on Dodge forecasts for 2024 and 2025 and assumed a four percent growth rate based on forecasts from Dodge, Mordor Intelligence, and Statista (TRC 2022). To account for the long lead time of commercial new construction, the study team also assumed that 50% of construction starts would be completed in the forecast year and 50% would be completed in the following year.

Compliance

In consultation with Xcel Energy, the study team assumed a 90% compliance rate for commercial building codes. This was based on prior code compliance research conducted by the utility. In this analysis, the study team assumed that 90% of new commercial square footage is compliant with the current

building energy code and 10% is compliant with the previous code. The study team did not assume any change in compliance over time. Note that this assumption likely overestimates compliance without a significant ramp up in market support for each code cycle, especially for the accelerated adoption scenario.

Energy Use Intensity

The study team estimated current energy use intensity for each building type based on DOE building prototype models for each segment. The study team used the Minneapolis Airport weather station as most representative of the geographic area under study.

The study team projected a 10% reduction in energy use for each code cycle, which is similar to PNNL estimates below. To develop EUIs for future code editions, PNNL examined BTO's Technology Roadmap reports and the goals set by the Standard 90.1 development committee (Tyler 2021).

Table 2. Commercial Future Code Energy Reduction Factors (ASHRAE 90.1 2016 = 1.00) (Source: PNNL)

End Use	IECC 2024 90.1-2022	IECC 2027 90.1-2025	IECC 2030 90.1-2028	IECC 2033 90.1-2031	IECC 2036 90.1-2034
Electricity – HVAC	0.80	0.74	0.68	0.62	0.56
Electricity – Lighting	0.86	0.80	0.72	0.64	0.56
Natural Gas – HVAC	0.80	0.74	0.68	0.62	0.56
Natural Gas – Plug and Process	1.00	1.00	1.00	1.00	1.00
Electricity – Plug and Process	1.00	1.00	1.00	1.00	1.00

Office EUI is a weighted average of small/medium and large office, based on information from Slipstream's Minnesota Commercial Energy Baseline and Market Characterization Study

Code Adoption Schedule

In its analysis, PNNL classified Minnesota's code adoption schedule as "moderate" and assumes a four-year lag in the adoption of ASHRAE 90.1 standards (Tyler 2021). The accelerated adoption scenario assumes that the state adopts the latest ASHRAE 90.1 standard within one year of its publication. The table below shows the year of adoption for each standard for the two adoption scenarios.

Table 3. Schedule of Building Energy Code Adoption

ASHRAE Standard	"Business as Usual" Adoption	Accelerated Adoption
90.1-2016	2019	2019
90.1-2019	2024	2022
90.1-2022	2026	2024
90.1-2025	2029	2025
90.1-2028	2032	2028
90.1-2031	2035	2031
90.1-2034	2038	2034

Code Adoption Scenarios

The study investigated four core adoption scenarios plus an additional maximum efficiency/electrification scenario. These adoption scenarios were:
- **Baseline Scenario** – Adoption lag of 4 years, based on "Moderate" adoption classification by PNNL
- **Accelerated Scenario** – Assumes adoption of "each new published edition of ASHRAE 90.1 or a more efficient standard" in the year of publication
- **Accelerated Scenario with PV** – Accelerated Scenario plus installation of solar PV using a prescriptive requirement of 0.5 W/SF renewable capacity based on the gross floor area of the three largest floors
- **Goal Scenario** – Assumes a straight-line reduction in EUI from 2024 to 2036 to achieve an 80% reduction in annual net energy consumption, using ASHRAE 90.1-2004 as a baseline
- **Electrification Scenario** – Assumes all-electric buildings and maximum efficiency

Results

Michaels Energy modeled out energy consumption in Minnesota's commercial sector for each of the scenarios described above and compared the differences in total consumption.

While the accelerated code adoption scenarios do not bring the overall new construction market to the goal of an 80% net energy reduction, the impacts vary considerably by building segment. Figure 2 shows the 2036 modeled kBtu for each building segment as a share of the ASHRAE 90.1-2004 baseline. Overall, the accelerated code adoption and accelerated with PV scenarios only get to about 40-50% of the 2004 baseline. Electrification and aggressive energy efficiency measures can come close to the target of 20% for some segments, such as small office and education, but not all.
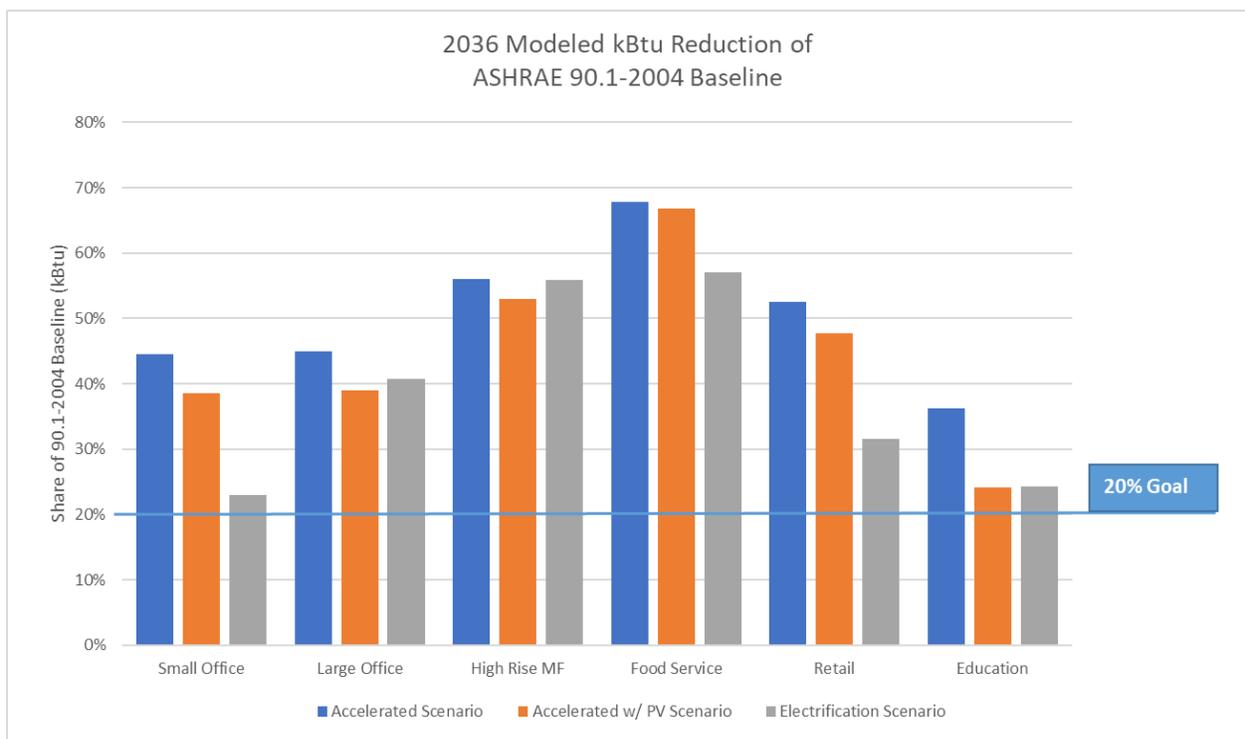

Figure 2. Year 2036 Modeled kBtu Reduction of ASHRAE 90.1-2004 Baseline

The study team found that some building segments, such as high-rise multifamily and food service, do not come close to meeting the 2004 baseline goal. This is primarily due to the physical constraints of the building types or their inherent end uses (e.g., cooking equipment and ventilation in food service facilities). Because high-rise multifamily buildings account for more than half of new commercial building stock in Minnesota, the effect of this segment's energy intensity overwhelmingly impacts the ability of the overall market to meet the goal.

Table 4 shows the impact of major end uses and fuels by comparing the modeled 2036 energy consumption to the 2004 baseline. Notably, energy used for lighting in high rise multifamily buildings and natural gas used for HVAC in food service and retail primarily drive the high energy intensity of those building segments.

Building Type	Electric - HVAC (kWh)	Electric - Lighting (kWh)	Natural Gas - HVAC (Mbtu)	Total Site Energy (kBtu)	Total Site Energy w/ PV (kBtu)
Small Office	50%	21%	52%	45%	37%
Large Office	65%	26%	37%	45%	43%
High Rise MF	55%	58%	56%	56%	54%
Food Service	57%	19%	77%	68%	67%
Retail	43%	25%	73%	52%	48%
Education	43%	20%	37%	36%	24%

Table 4. Share of Modeled Energy Consumption of Building Segments and End Uses in 2036 Compared to 2004 Baseline

Since the motivation for the research was related to Xcel Energy's Minnesota electric resource plan filing, Michaels Energy performed additional analysis focused on the system-wide impacts of the various code adoption scenarios. Figure 3 illustrates the different levels of site electricity consumption for commercial new construction from 2024 to 2036 for each scenario.

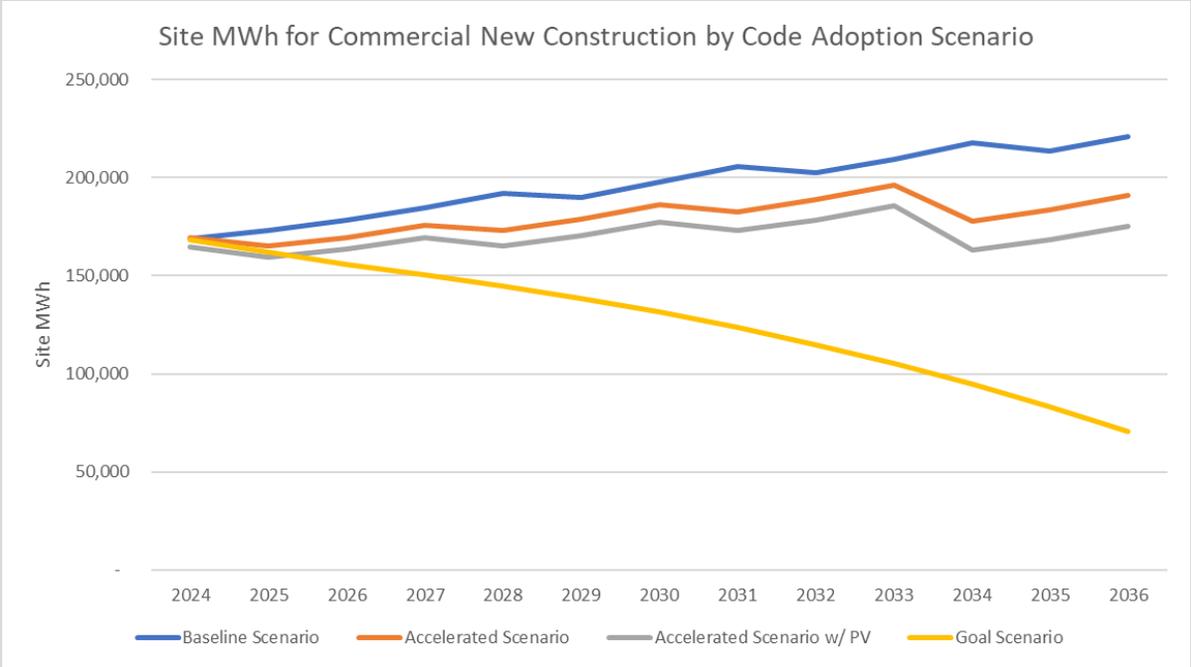**Site MWh for Commercial New Construction by Code Adoption Scenario**

Figure 3. Total Site MWh for Commercial New Construction by Code Adoption Scenario

In the baseline scenario of a four-year adoption lag, total site electric consumption from commercial new construction in Minnesota is expected to grow from 169 GWh in 2024 to 221 GWh in 2036, represented by the blue line in Figure 2. By accelerating the adoption of new building energy codes and including on-site solar generation, a total of 216 GWh and 340 GWh, respectively, can be saved from 2024 to 2036. However, neither of those scenarios will achieve the goal of 80% reduction in annual net energy consumption by 2036, using ASHRAE 90.1-2004 as a baseline. In that scenario, the total site electric consumption would need to drop to 71 GWh in 2036, a total savings of 910 GWh over the period.

In addition to the four core scenarios, the study team also modeled a scenario assuming all-electric buildings and maximum efficiency to understand the effect of electrification on the grid. The study team began with existing code and assumed aggressive but realistic technology improvements. The modeled building and equipment characteristics were specific to needs of each business segment/building type. As shown in Figure 4, the maximum electrification scenario would increase Minnesota's total site electric consumption for commercial new construction in 2036 to 420 GWh.
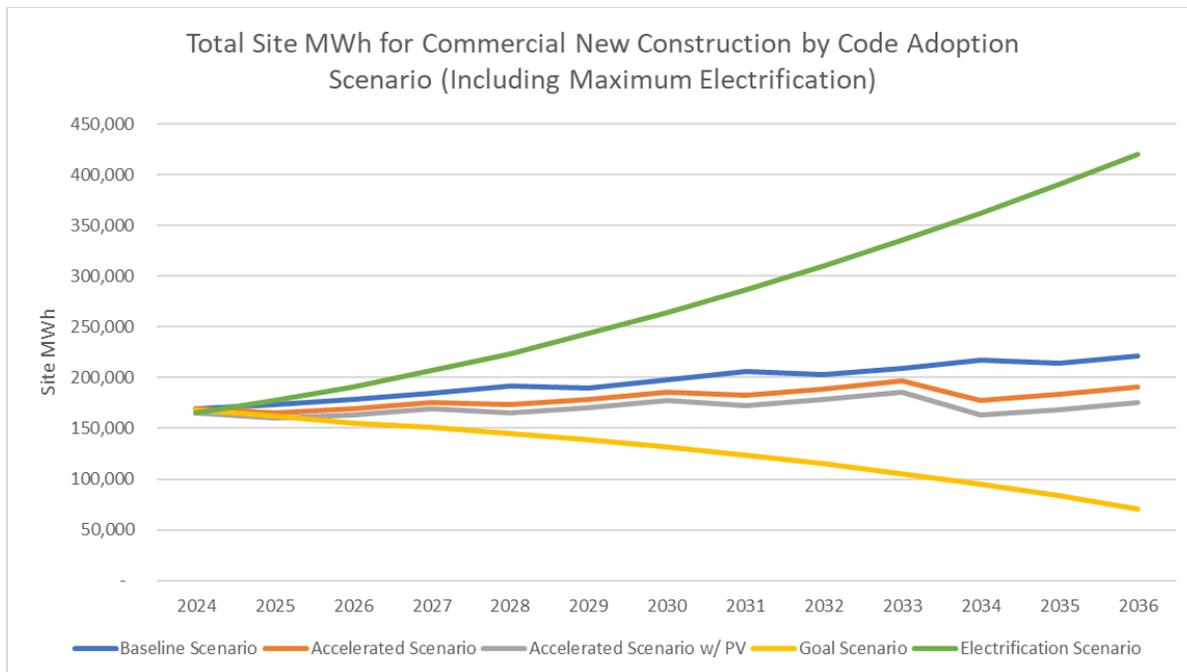
Figure 4. Total Site MWh for Commercial New Construction by Code Adoption Scenario including Maximum Electrification

Conclusions

There are three key high-level conclusions from the results detailed above. First, initial analysis suggests that the state policy targets will be difficult to meet relying only accelerated code adoption but achievability is widely varied across building types. Second, simplifying assumptions that were necessary to complete this study may not be appropriate in other jurisdictions or even in a future update of this research without first examining current market data and industry context. Finally, the modeling validates the seemingly logical conclusion that the code adoption path could have profound effects on utility system planning.

Variability

Variability in different sectors' ability to achieve the prescribed EUI reduction seems to be a profound issue that is rarely discussed in the industry. This may be partially a result of simplifying assumptions that were necessary for this research project but certain sectors, especially multifamily housing, seem to face significant challenges without transformational new efficiency technologies. As such, it is likely that assessment of the state policy goal to reduce EUI through building codes cannot be analyzed on a binary "on track" or "falling short" basis without looking at specific building types—in the same way that the approach to assessing compliance has evolved from "pass" or "fail" to calculating performance relative to a fully compliant building. One possible approach is a "portfolio-wide" approach that might achieve even greater EUI reductions in some segments while letting others achieve less. While this may be desirable from a state policy perspective, considerations of fairness and/or cost shifting from certain business types to others would likely arise. In addition, a portfolio-level approach would make achievement of the policy goal more susceptible to market-level shifts that are not entirely with the control of those responsible for administering the code (i.e., if the multifamily segment grows or diminishes, that can affect the degree to which achieving this policy is on or off track).

Complexity

Combining the increased difficulty of modeling distributed generation, efficiency, and electrification measures together with the intricacies design teams encounter when pursuing compliance with a higher-performing code introduces high levels of complexity to this analysis. This project mitigated some of that by focusing on a smaller number of high impact building types. However, we see expanding to include other end uses as a possible future activity. This requirement to revisit simplifying assumptions does limit the scalability of the approach to some extent. For example, building climate is naturally a factor that one would update when replicating this analysis in a different jurisdiction. There is an additional underlying assumption that, in choosing the high-volume segments, we would also be choosing the segments with greatest impact on overall energy consumption. However, in a place where space conditioning (especially space heating) is not such a dominant energy-consuming load, it would be necessary to consider whether permitted building square footage is the right metric to consider when prioritizing segments to model.

System Planning

The near quadrupling of electricity demand between the hypothetical "goal scenario" that presumes a proportional reduction in electric use and the electrification scenario that gets closest to achieving the state policy with known technologies is an exceptionally impactful finding. Addressing this tension between conservation and decarbonization emphasizes the importance of closely linking utility program, code advancement, and utility program decisions to ensure that pursuit of the state policy goal to improve building performance does not compromise the decarbonization trajectory of the electric grid.

Next Steps

A few key next steps related to evolution of the study resulted from the results and conclusions of the research. Xcel Energy plans to address some of these through its Energy Conservation and Optimization (ECO) portfolio while others involve broader consideration.

Existence of energy code support programs is an important factor in confidently planning for the accelerated adoption of commercial energy codes. Recent energy code compliance research [LeZaks et. al., 2020] has shown potential to close a "savings gap" between non-residential energy code design and as-built performance. This effect could be amplified when codes move more quickly and in larger increments. Considering this not just in program design but also in system planning is important for efforts to decarbonize an increasingly complex grid. Forgoing support for each code increment or failing to account for this lack of compliance could lead to unnecessary grid strain. Conversely, omitting the effect of the advancing codes that result from Minnesota's legislation could lead to inefficient grid investments. The ideal solution is to better predict how buildings will improve and then ensure that they achieve close to the designed performance.

Another next step is to examine whether similar legislation related to residential codes will need an analogous research effort. The residential policy passed a year after the commercial code but is likely to have very different effects from a utility system planning perspective due to the narrower distribution of building types and the longer interval since the last code update. Investigation of whether this approach or a different approach will be an important first step.

Finally, the research team plans to explore a sensitivity investigation to determine the degree of change in results and conclusions if key assumptions about building types and end uses are varied. Related to this, a comparison between the measures that were modeled to the code and amendments being discussed for the next non-residential energy code would be an important calibration of the technologies that the team assumed would be viable in future code updates.

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