ACEEE American Council for an Energy-Efficient Economy

TOPIC BRIEF

Using Monitoring-Based Building Commissioning to Achieve Substantial Energy, Demand and Emissions Savings

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Key Findings

- Monitoring-based commissioning (MBCx) is a process that maintains and continuously improves building performance over time.
- We examined six leading programs. Across these programs, energy savings and peak demand savings averaged approximately 9%. Linking MBCx with automated demand response might be able to roughly double the peak savings.
- One study finds an average simple payback period of about two years.
- We found an opportunity to reduce electricity use by nearly 50,000 million kWh (GWh), fuel use by over 100 trillion Btu, energy bills by about $7 billion, and electric peak demand by over 20,000 MW. To put these savings in perspective, the electricity savings are similar to the annual electricity consumption of Arkansas and the peak demand reductions are more than the power output of 20 large 1,000-MW power plants.
- Total costs in a New York State program were about $1 per sq. ft. with the program paying about 25% and owners and managers paying the rest. This program shows that building owners and managers can be willing to pay a large share of costs, provided they believe the benefits are substantial.
- Most programs emphasize buildings with floor area over 50,000 sq. ft. and that already have building energy management systems that MBCx can optimize. A program run by Commonwealth Edison in Illinois shows that in addition to full services for large buildings, simplified services for small buildings (particularly chains and school systems) can achieve substantial savings.
- There are several options utilities and other program implementers can use to encourage MBCx, including comprehensive multipronged efforts, market-transformation efforts to establish a MBCx market, prescriptive or custom rebates targeting energy management systems, and automated demand response.
- We recommend that automated demand response be included in MBCx programs and that programs seek to leverage fault detection and diagnostic analytics.
- Many program implementers are looking for new ways to save large amounts of energy as savings from lighting programs decline due to the rapid adoption of LED lighting. MBCx can help to fill this gap.

Monitoring-Based Commissioning

Monitoring-based commissioning (MBCx) is a process that maintains and continuously improves building performance over time (Kramer, Crowe, and Granderson 2017). Sometimes also called "continuous commissioning®" or "ongoing commissioning," MBCx typically begins with properly commissioning a building so systems operate as intended (either new building commissioning or "retrocommissioning" an existing building) and then continuing to monitor and analyze large amounts of data on a continuous basis in order to improve operations and also spot and address problems (e.g., a stuck damper) as they occur. Data may be monitored using an existing building automation system (BAS), or analytics can be enhanced using a third-party energy management and information system (EMIS) such as fault detection and diagnostics (FDD) software (see figure 1). To capture BAS, EMIS, and FDD together, we use the term energy management system (EMS).

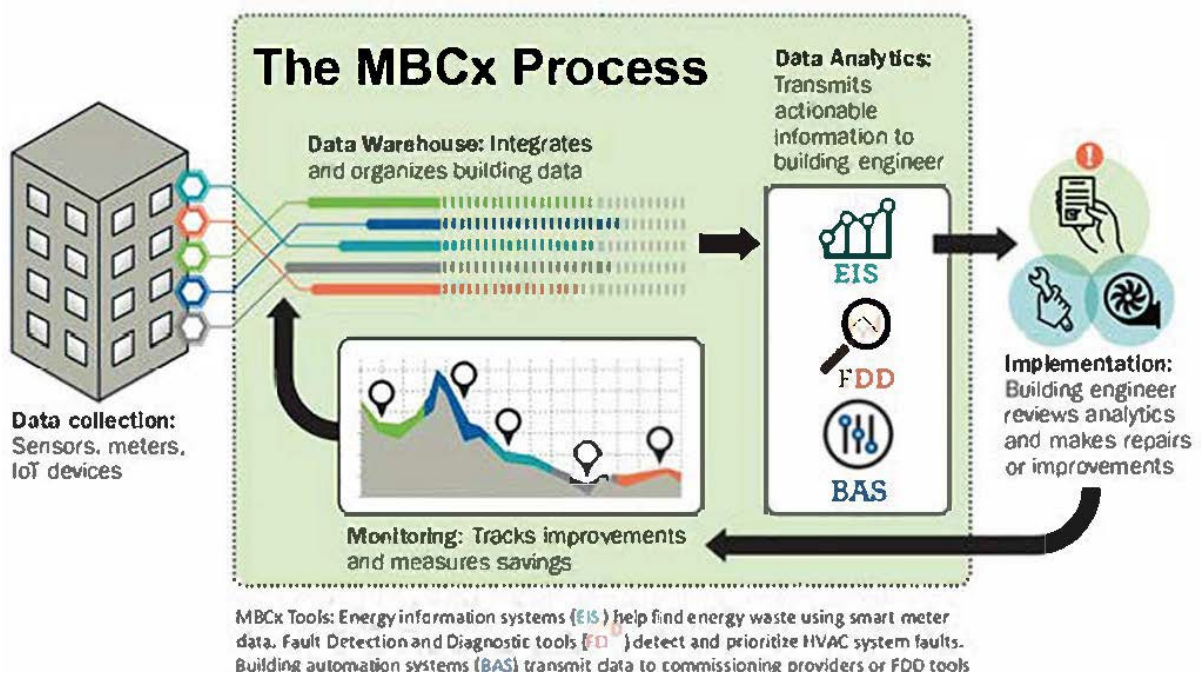

Figure 1. Overview of the typical MBCx process. Source: Kramer et al. 2020.

As discussed in the next section, MBCx energy and demand savings average approximately 9% and thus MBCx for existing commercial buildings can be a substantial energy saver, helping utilities and other program implementers achieve large energy and demand savings. Many program implementers are looking for new ways to save large amounts of energy as savings from lighting programs decline due to the rapid adoption of LED lighting. MBCx can help to fill this gap.

Monitoring-based commissioning is a key application of broader efficiency strategies such as intelligent efficiency (ACEEE 2018), grid-interactive efficient buildings (GEB) (Perry, Bastian, and York 2019), and active efficiency (ASE 2023).

National Savings Scenario

To help put this savings opportunity into perspective, using data from the *Commercial Building Energy Consumption Survey* (EIA 2022a) we estimated how much energy and money can be saved and electric peak demand reduced with widespread application of MBCx. Our analysis is shown in table 1. We find an opportunity to reduce electricity use by nearly 50,000 million kWh (GWh), reduce fuel use by over 100 trillion Btu, reduce commercial building energy bills by about $7 billion annually, and reduce electric peak demand by over 20,000 MW. To put these savings in perspective, the electricity savings are similar to the annual electricity consumption of Arkansas (EIA 2022c), and the peak demand reductions are more than the power output of 20 large 1,000-MW power plants. These peak demand savings include demand savings associated with the energy savings, and also include additional savings that are possible by preprogramming building controls (directly in the BAS or through third-party EMIS software) to undertake specified actions when the electric system reaches a critical peak and demand response programs are triggered.

Table 1. Energy and demand savings from widespread application of monitoring-based commissioning in the United States

	Data	Units	Source
Buildings above 50,000 sq. ft.	48,398	million sq. ft.	EIA 2022a (2018 CBECS table b7)
Percentage ultimately participating	80%		ACEEE estimate
Buildings 5,000–50,000 sq. ft.	39,999	million sq. ft.	
Percentage ultimately participating	10%		ACEEE estimate (primarily chains)
Participating floor area	42,718	million sq. ft.	
Average baseline kWh use	12.6	kWh/sq. ft.	EIA 2022a (2018 CBECS table c13)
Average baseline Btu fuel use	28.1	thousand Btu/sq. ft.	EIA 2022a (2018 CBECS table c1)
Average percentage savings	9%		Based on Texas A&M, LBL, and NYSERDA results
Electricity savings (million kWh)	48,482	million kWh	
Fuel savings (trillion Btu)	107,896	billion Btu	
Average commercial electricity price	$ 0.122	$/kWh	For 2023 from EIA 2023 (Annual Energy Outlook)
Average commercial gas price	$ 10.33	$/million Btu	For 2023 from EIA 2023 (Annual Energy Outlook)
Annual energy bill savings	7.0	billion $	
Average kWh/peak kW	4,441		EIA 2022b (Electric Power Annual, table 10.1)
Electricity demand savings			
From basic MBCx	10,918	MW	
Additional from Auto DR	13,344	MW	Add 11% (low end of PG&E range)
Total	24,261	MW	

Notes: CBECS = Commercial Building Energy Consumption Survey; LBL = Lawrence Berkely National Laboratory; NYSERDA = New York State Energy Research and Development Authority; PG&E = Pacific Gas & Electric Company.

Recent Experience

TEXAS A&M

Continuous commissioning® was developed and trademarked in the 1990s at Texas A&M University as part of their work on the Texas LoanSTAR program (Claridge et al. 2000). As of 2021, Texas A&M was involved in 197 projects involving 592 buildings including 316 education buildings, 141 health care facilities, 13 laboratory facilities, 32 office buildings, and 90 other facilities. They summarized the results of these projects in a 2021 paper (Ruffin, Claridge, and Baltazar 2021). The 592 buildings averaged 99,800 sq. ft. of floor area. Total annual energy cost reductions were nearly $30 million (2017$). Savings by building are summarized in table 2. A simple average of the median savings by building is 9.4% electricity savings, 8.25% electric demand savings, and 15.75% gas savings.

They recently completed six projects on several Veteran's Administration facilities that ranged from 260,000 to 1,250,000 sq. ft. and the implementation cost ranged from $0.42–1.30 per sq. ft. (D. Claridge, director of Energy Systems Laboratory, Texas A&M University, pers. comm., April 2023).

Table 2. Energy savings percentages compiled by Texas A&M, median [minimum-maximum]

Building type	Electricity	Demand	Natural Gas
Educational	13% [2%–32%]	14% [3%–26%]	33% [10%–65%]
Healthcare	5% [1%–35%]	10% –	10% [1%–53%]
Laboratory	2% [0%–6%]	–	–
Office	14% [1%–43%]	4% [1%–6%]	11% [0%–49%]
Miscellaneous	13% [2%–45%]	5% –	19% [3%–76%]

Note: Ranges include just positive energy savings.

Source: Ruffin, Claridge, and Baltazar 2021

LAWRENCE BERKELEY NATIONAL LABORATORY

Berkeley Lab ran a Smart Energy Analytics Campaign funded by the U.S. Department of Energy over the 2016–2020 period that worked with 104 organizations and 6,500 buildings covering over 500 million sq. ft. of floor area. The campaign had significant participation from both the public and private sector, and across many market sectors. Program participants used two types of EMIS to support their MBCx efforts: energy information systems, or EIS (systems that store, analyze, and display building energy data), and fault

detection and diagnostic tools, or FDD (systems that automate the process of detecting faults and suboptimal performance of building systems and help to diagnose potential causes). In general, savings tend to increase from year-to-year as building managers take additional steps each year in response to the data they receive (see figure 2). Median documented annual energy savings in the second year of installation were 3% for energy information systems and 9% for fault detection and diagnostics (Kramer et al. 2020). Program participants paid, on average, $0.02 per sq.ft. for their EIS software and $0.09 per sq. ft. for their FDD software. When considering the additional costs to manage MBCx and resolve the issues uncovered, program participants saw simple payback periods of approximately two years.

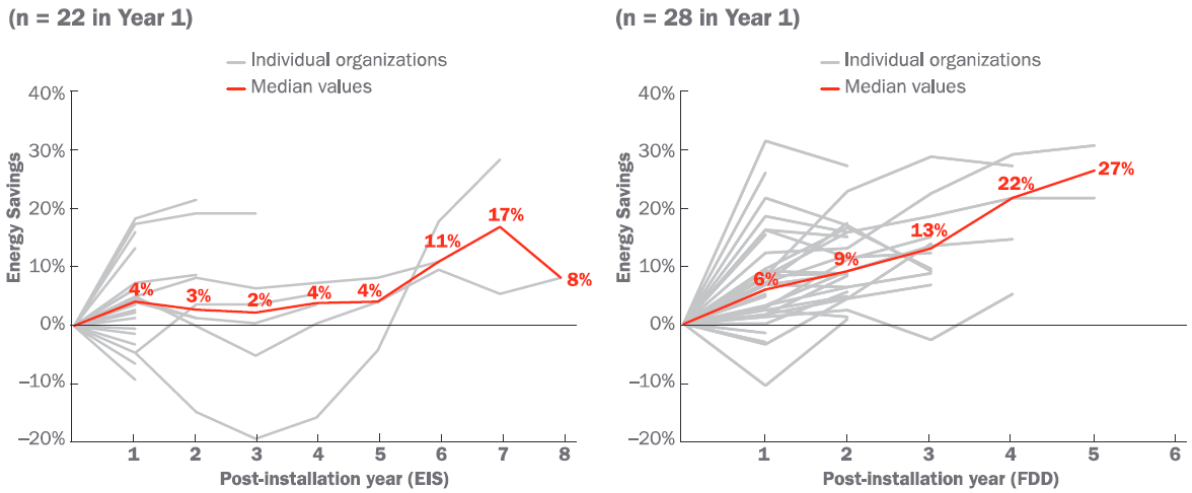

Figure 2. Percentage energy savings relative to year before energy management information system installation for organizations participating in the Smart Energy Analytics Campaign. Source: Kramer et al. 2020.

COMMONWEALTH EDISON

Commonwealth Edison (ComEd) is a large electric utility serving Northern Illinois including Chicago. They have operated a Retro-Commissioning Program (commissioning of existing buildings) since 2009. In the program's early years it targeted large commercial buildings, primarily offices, with a focus on kWh savings. Over time the focus broadened to other building types such as hospitals, schools, universities, and government buildings. Beginning in 2013, they added a MBCx component to drive deeper savings. Some buildings have now been enrolled in this MBCx program for up to seven years. In 2015 they added a simplified Retro-Commissioning Tune-Up program for smaller buildings. In 2017 a Virtual Commissioning path (entirely remote) was added as another pathway for reaching smaller buildings, particularly chains, bank branches, and school systems where lessons learned in one building can often be applied in related buildings under the same management.

In the early years, incentives emphasized conducting a retrocommissioning study. This has shifted more to incentives being paid for implementation of measure recommendations and measure verification after studies are completed. Incentives mostly go to service providers so

that they can provide their services for free. There is also a small incentive to the customer for savings achieved (now three cents per kWh). In the early years the program included five stages with review at each stage. Over time the program has been simplified, now often uses standard calculations, and is down to two stages. The number of participating customers has gradually increased, from just a few in the first year to over 250 in the most recent year. In recent years, three local gas utilities whose service areas overlap with ComEd have helped to fund the program, with costs split between the utilities based on electricity and gas savings (W. Kumphai and R. Tonielli, Commonwealth Edison, pers. comm., March 31, 2023).

Presently there are three subprograms—Monitoring-Based Commissioning for the largest buildings; Retro-Commissioning Flex, primarily for medium-sized buildings; and Virtual Commissioning that includes smaller buildings, particularly chains and other groups of buildings under common management. These represent an evolution from the programs as originally offered. Information on these three programs can be found in table 3.

Table 3. Commonwealth Edison retrocommissioning options

Retro-Commissioning Options			
	Retro-Commissioning Flex (RCx)	Monitoring-Based Commissioning (MBCx)	Virtual Commissioning (VCx)
Building Size	Any	> 150,000 ft^2	Any
Building Annual Energy Usage	> 0.5 GWh	> 3 GWh	Any
Peak Demand	> 100kW		< 500 kW
Energy Savings	5-10% of annual usage	10-15% of annual usage	5-15% of annual usage
Incentives	Fully-funded RCx Flex study covering the costs of engineering services Performance-based incentive up to implementation cost	Fully funded MBCx study covering the costs of monitoring software and engineering services Performance-based incentive up to implementation cost	Fully-funded remote analysis of energy usage and technical assistance
Minimum Financial Commitment	$1,000 to $15,000 on implementation of energy conservation measures based on project size	None	None
Project Payback Period	< 1.5 years for implemented energy improvements		< 6 months
Minimum Customer Staff Requirement	3-6 hours per month	10 hours per month	None
Average Project Duration	6-15 months	18+ months	3 months

Source: comed.com/WaysToSave/ForYourBusiness/Pages/FactSheets/RCxOptions.aspx

Overall, since program inception, the program has served commercial buildings with more than a combined 500 million sq. ft. of floor area. Results from the most recent impact evaluation on the program are summarized in table 4. This evaluation looked at both gross (total) savings at well as net savings attributable to the program. They found a net-to-gross savings ratio of 94%.

Table 4. Summary of calendar year 2021 results for Commonwealth Edison Retro-Commissioning (RCx) and Virtual Commissioning (VCx) Programs

Item	Data
Number of participants	104 for RCx, 174 for VCx
Average life of measure savings	8.5 years RCx, 7.3 years for VCx
Gross electric savings	45,838,183 kWh
Gross peak demand reduction	3,496 kW
Gross gas savings	68,573 therms for RCx
Net-to-gross ratio	0.94 for RCx, 1.0 for VCx
Net electric savings	44,436,322 kWh
Net peak demand reduction	3,374 kW
Net gas savings	64,459 therms for RCx (not evaluated for VCx)

Source: Guidehouse 2022a, 2022b

NYSERDA REAL TIME ENERGY MANAGEMENT PROGRAM

The New York State Energy Research and Development Authority (NYSERDA) is a state agency that, in addition to research and development (R&D), operates statewide energy efficiency programs that focus on helping low-income New Yorkers and working to transform energy efficiency markets in the state. The Real Time Energy Management (RTEM) program, begun in 2016, seeks to accelerate market adoption of RTEM systems and services. The focus is on installing cloud-based systems that upload data from building energy management systems and analyze the data to develop actionable insights. Building owners and managers can apply for project support, which generally covers 30% of the installation cost and 30% of the service fees for up to five years. Owners and managers need to choose from a qualified-vendor list in order to ensure quality products and services.

Over time, the program gradually evolved. At first, only commercial buildings were eligible. In 2018, multifamily and industrial buildings were added to the program. Initially, participants were small buildings and vendors, but by the second year, large property owners and vendors started entering the program. Larger projects took longer to develop and to be incorporated into building management budgets. In 2020, the value of these systems and services was enhanced as part of a response to COVID-19 in offices and the program was oversubscribed. In 2020 NYSERDA stopped accepting new commercial participants and in 2021–2022 they stopped accepting new multifamily participants as local utilities started programs in these areas. The RTEM program moved on to focus on systems and services for tenant spaces.

As part of promoting the program, NYSERDA has prepared a set of case studies on a variety of individual building sites, and also one case study on how a major New York City property manager used the program for eight large office buildings (NYSERDA 2019).

As of May 2023, the program includes over 1,200 sites representing nearly 300 million sq. ft. of building floor area. Specifics on program participation and cost by sector are listed in table 5.

Table 5. RTEM participation and expenditures

Sector	Number of sites	Floor area (sq. ft.)	NYSERDA incentives	Private investment
Commercial	800	200,188,596	$54,896,875	$179,454,057
Industrial	33	31,770,470	$7,103,273	$19,841,295
Multifamily	371	60,398,415	$13,435,379	$40,183,895
Small to Medium Business	12	303,428	$702,440	$1,806,672
Total	1,216	292,660,909	$76,137,967	$241,285,919

Source: NYSERDA 2023

Based on data in the table, NYSERDA costs are averaging $0.26 per sq. ft. of floor area. For each NYSERDA dollar, building owners and managers are investing just over $3. Program staff report that approximately 75% of participating building floor area is in New York City, and they estimate that in New York City the program is serving about 25% of the buildings with a floor area above 50,000 sq. ft. As of the end of 2021, based on initial vendor reporting, they estimate that the program is saving 260 million kWh annually as well as 393 billion Btu of natural gas and 38 billion Btu of fuel oil. Natural gas savings are particularly high due to a special initiative to use the program to address natural gas capacity shortages (C. Glavey-Weiss, project manager, NYSERDA, pers. comm., June 2023). On average the program is reducing electricity use by 8.2% and overall energy use by 7.2% (Glavey-Weiss 2023).

XCEL ENERGY MANAGEMENT SYSTEM (EMS) PROGRAM

Xcel Colorado's EMS program offers incentives proportional to the volume of energy saved. It is a custom energy efficiency program available to all commercial and industrial customers, but is largely targeted at commercial customers with a demand of 500 kW or greater. Xcel markets the program through trade allies, as well as directly to customers through account managers. In 2015, Xcel expanded the program to include software programs that allow customers to see and analyze real-time energy data. The program covers the entire range of EMS ranging from simple EIS and FDD systems to more complex systems that enable operators to visualize data and identify low- or no-cost behavioral measures customers can take to reduce their energy usage (ACEEE 2018).

As an example, Xcel provided the operator of a large office building in Denver an incentive of more than $180,000 to purchase EMS equipment including a main server, software, and licenses to control the building's heating, ventilation, and air-conditioning (HVAC) system. The building saw a 20% reduction in overall electricity use (1,116 MWh saved) and a 25% reduction in overall district steam energy use in just six months (Xcel 2015).

The program targets both electric and natural gas customers. From 2012–2016, the program included 316 electric customers and 176 gas customers; this includes some customers who participated as both. Expenditures over this period averaged just over $1 million per year (ACEEE 2018). Over the 2017–2021 period an additional 231 projects were undertaken (N. Minderman, DSM policy and strategy consultant, Xcel Energy, pers. comm., June, 2023).

In recent years, participation has slowed down as more than half the projects that vendors proposed did not meet cost-effectiveness criteria and could not move forward. After having several projects declined, some vendors stopped submitting projects or submitted in other categories not subject to cost-effectiveness testing at the individual project level. The likelihood that many of the most cost-effective projects have already been implemented probably contributed to these challenges. An independent evaluation conducted in 2022 (TRC 2023) found that cost effectiveness was being too tightly evaluated and did not account for the fact that customers invest in EMS for multiple reasons, not just cost effectiveness. The evaluation recommended charging only half of the incremental cost against energy and demand savings. The evaluation also recommended adding prescriptive rebates and increased training for trade partners on peak load shifting. Xcel agrees with these recommendations and has proposed to make these changes, as well as efforts to bring their controls/EMS and demand response program more closely together. Xcel Energy has recently found more success with its EIS offering, which focuses on leveraging the systems that customers already have in place to provide performance-based incentives for improved operations (Xcel 2023; N. Minderman, DSM policy and strategy consultant, Xcel Energy, pers. comm., June 2023).

PG&E AUTOMATED DEMAND RESPONSE (ADR) PROGRAM

Pacific Gas & Electric Company's (PG&E) ADR program provides funding for demand-reducing equipment for customers where the equipment can receive a signal from PG&E to initiate a series of automatic, customer-defined, and preauthorized actions during demand response (DR) events. Rebates of up to $200 per kW of preprogrammed demand reductions help customers offset 75% of the purchase and installation costs of new behind-the-meter technologies and controls that are capable of receiving ADR signals for DR events. This makes it easier for customers to participate in various PG&E DR programs such as Peak Day Pricing (discounted rates for most of the summer but higher prices on 9–15 peak days), Capacity Bidding, and DR Auction Mechanism (the latter two provide payment for load reductions during DR events with bidding handled by aggregators). ADR signals trigger preprogrammed and automated energy management and curtailment strategies that reduce the burden on customers to manually reduce their energy usage and improve the reliability of the expected load reduction.

The ADR program offers two application processes, the Standard Application and the FastTrack Application. The Standard Application process is primarily for large commercial, industrial, and agricultural customers as it requires a robust calculation of curtailment kW typically prepared by engineers and analysts. The FastTrack Application process is available for small and medium businesses (e.g., many retailers and offices) who have an average peak summer demand that is ≤ 200 kW per service account, along with specific sectors of business customers who have under 499 kW average peak summer demand per service account. This approach provides a streamlined incentive calculation process for projects associated with specific building types and for HVAC and lighting (PG&E 2022).

Each customer can choose different automated DR strategies. For example, some customers pre-cool their buildings when a DR event is likely. Others use various energy storage techniques such as ice storage. Agricultural customers can send signals to stop pumps. And still others program their building energy management systems to make a variety of modifications such as higher temperature setpoints, lower fan speeds, and reduced fresh air intake just for the few hours of a DR period.

In 2022, the ADR program included 86 customers and 910 service accounts (many customers have more than one participating site). ADR attributed load reductions totaled 87 MW. Agricultural, retail, and industrial customers accounted for the largest committed reductions, with offices a distant fourth. Load reductions from offices used to be higher when PG&E had a summer afternoon peak period but reductions declined when PG&E moved to a summer evening peak (e.g. 6–8 p.m.), which is after the workday for most offices (Energy Solutions 2023).

For participating offices, on average, ADR reduced their peak demand by 16% when the peak was during the afternoon, but since the shift to an evening peak, the average is 11% among buildings that participated under both peak periods (and not including several buildings that dropped out after the peak period moved to the evening). They also found that the baseline demand was lower for the evening peak than for the afternoon peak. These results are illustrated in table 6.

While the PG&E program is funded through a DR proceeding for DR benefit, we see obvious potential to combine ADR and MBCx, to fully leverage the automation/analytics infrastructure applied through MBCx. Combining both approaches would maximize both energy efficiency and demand reduction impacts, including by programming building energy management systems to easily participate in DR events and significantly increase MBCx peak demand savings and increase cost effectiveness.

Table 6. Comparison of ADR office customer data for afternoon and evening peak periods

	12–6 p.m. peak window (previous)			4–6 p.m. peak window (current)		
	2017–2019 average event period baseline (kW)	2017–2019 average event load shed (kW)	2017–2019 load shed % of baseline	2021–2022 average event period baseline (kW)	2021–2022 average event load shed (kW)	2021–2022 load shed % of baseline
Selected ADR Office Customers	563	93	16%	266	29	11%

Source: Kevin Hurless, senior project manager, Energy Solutions (implementer of PG&E ADR program)

Conclusions and Recommendations

Many program implementers are looking for new ways to save large amounts of energy as savings from lighting programs decline due to the rapid adoption of LED lighting. MBCx can help to fill this gap.

Across the programs we examined, energy savings averaged approximately 9% and peak demand savings appeared to be similar. Total costs in the NYSERDA program were about $1 per sq. ft. with NYSERDA paying about 25% and owners and managers paying the rest. This is broadly consistent with Texas A&M's recent experience where total costs ranged from $0.42–1.30 per sq. ft. The NYSERDA program shows that building owners and managers can be willing to pay a large share of costs, provided they believe the benefits are substantial. The Commonwealth Edison program shows that in addition to comprehensive services for large buildings, simplified services for small buildings (particularly chains and school systems) can result in substantial savings. Key data based on the different programs are summarized in table 7.

Table 7. Summary data from programs

Metric	Data	Source
Energy and demand savings	9%	Based on Texas A&M, LBL, and NYSERDA results
Additional peak demand savings from automated demand response	11–16%	From PG&E program
Cost per sq. ft.	$1	From NYSERDA program, Texas A&M similar
Simple payback period	2–6 years	Low end from LBL, high end based on $1/sq. ft. and savings in table 1

Utilities and other program implementers can take a variety of approaches to encourage MBCx, including:

- A comprehensive multipronged effort along the lines of the Commonwealth Edison program (e.g., full MBCx, light commissioning, and virtual commissioning).
- A market-transformation effort to establish a MBCx market, along the lines of what NYSERDA has done in its RTEM program.
- Prescriptive, custom, or whole building performance-based rebates targeting EMS systems along the lines of the Xcel Energy program.
- Leveraging the growing adoption of EMIS and FDD analytics tools as a platform for MBCx, DR, and future GEB strategies.
- For all of these options, an automated demand response component can be included along the lines of the PG&E Auto DR program.

The NYSERDA program has by far the largest savings (260 GWh/year) followed by the Commonwealth Edison program (44 GWh/year). In part, these programs stand out because New York City has the most extensive office building stock in the U.S. and Chicago also has a very large building stock, with offers for a wide range of building sizes.

Results from the programs we examined show that successful programs can result in substantial participation and savings. Other program implementers should consider similar programs, learning from and building on these examples. We recommend that automated demand response be included in MBCx programs. MBCx programs have achieved substantial energy and demand savings; the addition of ADR has the potential to significantly increase peak demand reductions and benefits.

References

ACEEE. 2018. "Toolkit: Intelligent Efficiency in Commercial and Industrial Buildings." www.aceee.org/toolkit/2018/05/intelligent-efficiency-commercial-and-industrial-buildings.

ASE (Alliance to Save Energy). 2023. "Active Efficiency." www.ase.org/categories/active-efficiency.

Claridge, D., C. Culp, M. Liu, S. Deng, W. Turner and J. Haberl. 2000. "Campus-Wide Continuous Commissioning of University Buildings." *Proceedings of the 2000 ACEEE Summer Study on Energy Efficiency in Buildings* 3: 101–12. Washington, DC: ACEEE. www.aceee.org/files/proceedings/2000/data/papers/SS00_Panel3_Paper08.pdf.

EIA (Energy Information Administration). 2022a. "Commercial Building Energy Consumption Survey (CBECS)." www.eia.gov/consumption/commercial/.

_____. 2022b. *Electric Power Annual 2021*. Washington, DC: EIA. www.eia.gov/electricity/annual/.

_____, 2022c. "US Electricity Profile 2021." www.eia.gov/electricity/state/.

_____. 2023. *Annual Energy Outlook 2023*. Washington, DC: EIA. www.eia.gov/outlooks/aeo/.

Energy Solutions. 2023. *2022 PG&E ADR Annual Report*. San Francisco, CA: PG&E..

Glavey-Weiss, C. 2023. *Real-Time Energy Management Program, Summary of Program Participation and Energy Results*. Albany, NY: NYSERDA. www.nyserda.ny.gov/All-Programs/Real-Time-Energy-Management.

Guidehouse. 2022a. *Combined Utility RetroCommissioning Impact Evaluation Report*. Oak Brook, IL: ComEd. Naperville, IL: Nicor Gas Company. Chicago: Peoples Gas and North Shore Gas. www.ilsag.info/wp-content/uploads/Combined-Utility-RCx-CY2021-Impact-Evaluation-Report-2022-04-14-Final.pdf.

_____. 2022b. *ComEd Virtual Commissioning Impact Evaluation Report*. Oak Brook, IL: ComEd. www.ilsag.info/wp-content/uploads/ComEd-VCx-CY2021-Impact-Evaluation-Report-2022-04-12-Final.pdf.

Kramer, H., E. Crowe, and J. Granderson. 2017. *Monitoring-Based Commissioning (MBCx) Plan Template*. Prepared by Berkeley Lab. Washington, DC: DOE. buildings.lbl.gov/sites/default/files/MBCx Plan Template_June 2017_Final.pdf.

Kramer, H., G. Lin, C. Curtin, E. Crowe and J. Granderson. 2020. *Proving the Business Case for Building Analytics*. Prepared by Berkeley Lab. Washington, DC: DOE. buildings.lbl.gov/publications/proving-business-case-building.

NYSERDA (New York State Energy Research and Development Authority). 2019. *Rudin Management: Using Real-Time Energy Management to Optimize NYC Commercial Building Operations*. Albany, NY: NYSERDA. www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Publications/Case-Studies/Commercial/CS-Rudin-Management.pdf.

_____. 2023. "Project Dashboard." www.nyserda.ny.gov/All-Programs/Real-Time-Energy-Management/Project-Dashboard.

Perry, C., H. Bastian, and D. York. 2019. *Grid-Interactive Efficient Building Utility Programs: State of the Market*. Washington, DC: ACEEE. www.aceee.org/white-paper/gebs-103019.

PG&E (Pacific Gas & Electric Company). 2022. *Pacific Gas and Electric Company 2023–2027 Demand Response Programs, Pilots, and Budgets, 2023 Bridge Funding, Prepared Testimony*. Docket No. 22-05-002, May 2. San Francisco: CPUC (California Public Utilities Commission). docs.cpuc.ca.gov/PublishedDocs/SupDoc/A2205002/4854/473872959.pdf.

Ruffin, A., D. Claridge, and J. Baltazar. 2021. "The Energy Savings Impact of the Existing Building Commissioning Process by Building Type." *Science and Technology for the Built Environment* 27 (10): 1505–21. www.tandfonline.com/doi/abs/10.1080/23744731.2021.1921492.

Xcel Energy. 2015. *1670 Broadway: Maximum Efficiency, Minimum Interruption*. Denver, CO: Xcel Energy. xcelenergy.com/staticfiles/xe/Marketing/Files/EMS-CO-Case-Study-1670-Broadway.pdf.

_____. 2023. *2022 Fourth Quarter Colorado DSM Roundtable Update*. Denver, CO: Xcel Energy. www.xcelenergy.com/staticfiles/xe-responsive/Company/Rates%20&%20Regulations/20A-0287EG_Q4%202022%20Quarterly%20DSM%20Program%20Update.pdf.

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