# THE STATUS AND PROMISE OF ADVANCED M&V

AN OVERVIEW OF "M&V 2.0" METHODS, TOOLS, AND APPLICATIONS

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## ABOUT ROCKY MOUNTAIN INSTITUTE

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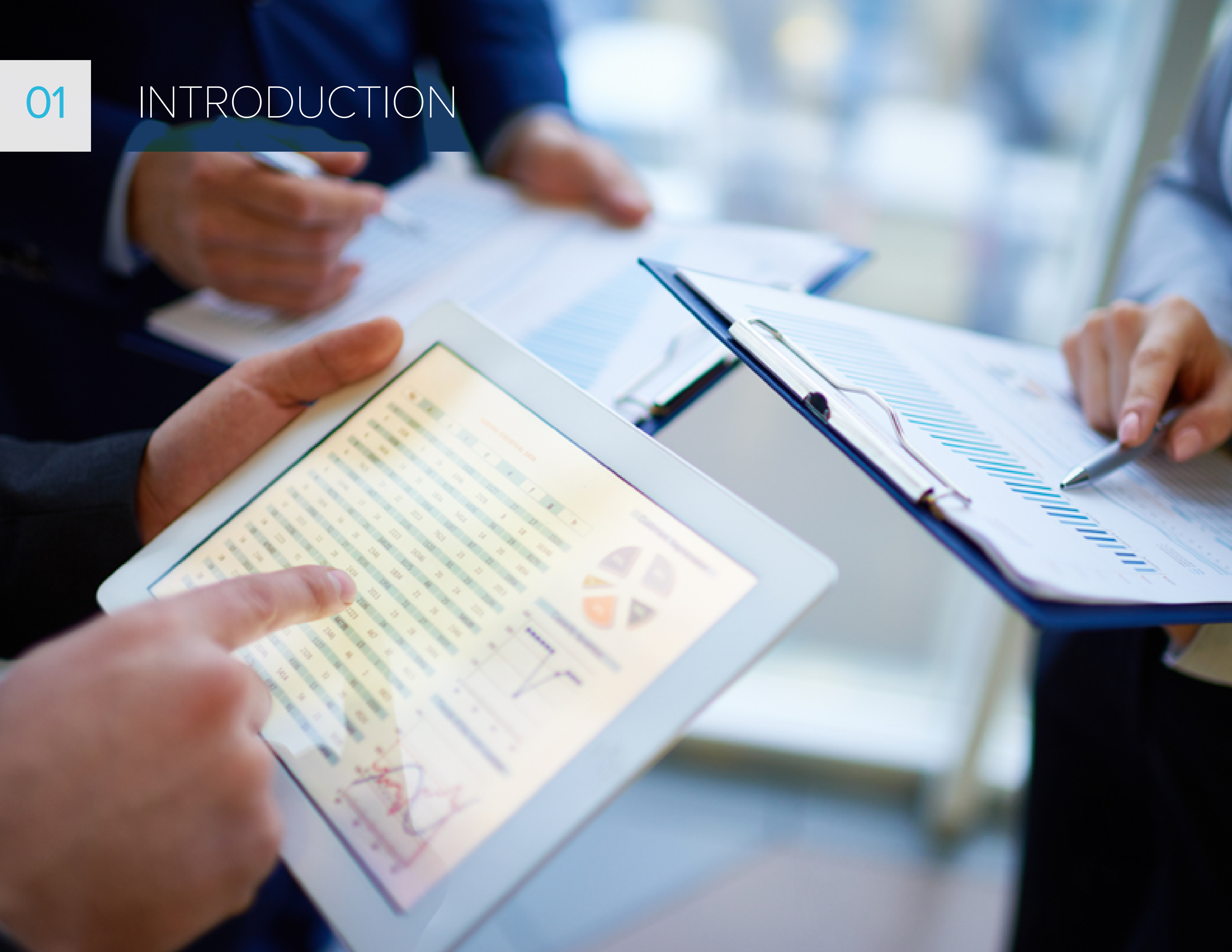
# 01 INTRODUCTION



# INTRODUCTION

Advanced measurement and verification (M&V) of energy efficiency savings, often referred to as M&V 2.0 or advanced M&V, is currently an object of much industry attention. Thus far, however, there has been a lack of clarity about what techniques M&V 2.0 includes, how those techniques differ from traditional approaches, what the key considerations are for their use, and what value propositions M&V 2.0 presents to different stakeholders.

The objective of this paper is to provide background information and frame key discussion points related to advanced M&V. The paper identifies the benefits, methods, and requirements of advanced M&V and outlines key technical issues for applying these methods. It presents an overview of the distinguishing elements of M&V 2.0 tools and of how the industry is addressing needs for tool testing, consistency, and standardization, and it identifies opportunities for collaboration.

In this paper, we consider two key features of M&V 2.0: (1) automated analytics that can provide ongoing, near-real time savings estimates, and (2) increased data granularity in terms of frequency, volume, or end-use detail. Greater data granularity for large numbers of customers, such as that derived from comprehensive implementation of advanced metering infrastructure (AMI) systems, leads to very large data volumes. This drives interest in automated processing systems. It is worth noting, however, that automated processing can provide value even when applied to less granular data, such as monthly consumption data series. Likewise, more granular data, such as interval or end-use data, delivers value with or without automated processing, provided the processing is manageable. But it is the combination of greater data detail with automated processing that offers the greatest opportunity for value.

Using M&V methods that capture load shapes together with automated processing can[1] determine savings in near-real time to provide stakeholders with more timely and detailed information. This information can be used to inform ongoing building operations, provide early input on energy efficiency program design, or assess the impact of efficiency by location and time of day. Stakeholders who can make use of such information include regulators, energy efficiency program administrators, program evaluators, contractors and aggregators, building owners, the investment community, and grid planners. Although each stakeholder has its own priorities and challenges related to savings measurement and verification, the potential exists for all to draw from a single set of efficiency valuation data. Such an integrated approach could provide a base consistency across stakeholder uses.

This paper stems from the authors' participation in the M&V 2.0 project team at Rocky Mountain Institute's 2016 e-Lab Accelerator. The project targeted current needs to improve energy efficiency valuation methods and models through real-time analytics. The authors established the content collaboratively, based on their unique perspectives from academia, evaluation consulting, software development, and efficiency program administration, and on their collective, ongoing work on this topic.

The paper considers advanced M&V concepts from different stakeholder perspectives in order to promote a comprehensive vision for its application and acceptance. The diverse backgrounds of the authors yield a collective view to serve as a starting point for coordinating and prioritizing industry efforts to support improved execution and impact of energy efficiency efforts, and of their measurement.

## M&V OVERVIEW

In the 1990s, methods emerged to improve the consistency of efficiency savings estimates and reduce the uncertainty of savings attributed to energy efficiency projects. Specifically, the work supported performance contracts for energy efficiency services with payments based on measured performance.

The established industry-accepted framework for M&V includes four approaches for determining verified savings, as outlined in the International Performance Measurement and Verification Protocol (IPMVP) and described in Table 1.[2] Considerations for selecting one of these four options for a given application include: (1) regulatory requirements, (2) the method's effectiveness in managing the risks of under- or overestimating energy savings, and (3) balancing the level of evaluation rigor and accuracy against the (project, program, or evaluation) M&V costs and the potential value of the saved energy.

### TABLE 1
INDUSTRY-ACCEPTED IPMVP M&V OPTIONS

| APPROACH | DESCRIPTION | MEASUREMENT BOUNDARY | TYPICAL APPLICATION |
|---|---|---|---|
| Option A<br>Key-Parameter Measurement | Short-term measurement of key parameters impacting energy use | Equipment or system | Lighting retrofit: power measured, hours estimated |
| Option B<br>All-Parameters Measurement | Short- or long-term measurement of all parameters impacting energy use | Equipment or system | Variable-speed drive retrofit of a pump: continuous measurement of pump kW |
| Option C<br>Whole Facility | Whole-building utility billing analysis | Building | Deep energy retrofit with system interactions |
| Option D<br>Calibrated Simulation | Calibrated building simulation modeling | Building and/or subsystem | Beyond-code new construction project with no existing baseline |

Evaluation, measurement, and verification (EM&V) is a process of assessing an energy efficiency program, including applying M&V and other methods to estimate program savings. EM&V can include:

- The M&V methods applied at the building level, with results expanded to the program level.
- The use of deemed savings values, with installations and key parameters verified by the evaluator, but without direct measurement of site performance (thus deemed savings is not considered a true M&V approach).
- Analysis of consumption data for program participants and a comparison group to determine savings for the program as a whole, and not necessarily for any individual facility or measure.

Key ways in which estimating savings for a program differs from estimating savings for the purpose of a performance contract include the following:

- Program impact evaluation focuses on estimating savings for the program as a whole, and does not necessarily validate savings for each individual project or facility.
- Program impact evaluation in many jurisdictions counts "gross" savings relative to the alternative technology that would otherwise have been installed. Thus, for natural replacement installations, savings are counted relative to standard efficiency equipment, not relative to the previously existing equipment. In these contexts, automated analysis comparing pre- and post-installation consumption patterns can be useful as early confirmation that equipment is (or is not) functioning as expected, but typically may not be useful as a basis for final evaluated savings unless subjected to additional adjustments.

Program impact evaluations in most jurisdictions count "net" savings as the portion of gross savings that is attributable to the program (that is, the installations or efficiency improvements that would not have occurred without the program). Net savings analysis using consumption data typically requires specification of an appropriate comparison group. Comparison group specifications, and analytic methods to control for comparison group limitations, depend on the program design. Except in cases where programs are delivered using random assignment to establish "treated" and "comparison" customer groups, there is no industry consensus on a generically valid selection process to create comparison groups.

### M&V APPLICATION CONSIDERATIONS

As indicated above, M&V is conducted for performance measurement of privately installed projects, as well as to determine the impacts of efficiency programs. In these two broad contexts, the measured savings may have a variety of uses, including the following:

- To determine savings for a particular installation, as a basis for determining payments from an end-use customer to a vendor
- To determine savings quantities for a collection of installations under a program, as a basis for determining payments from a program administrator to a program implementer
- To determine net savings for a total program for regulatory reporting purposes
- To determine the net savings attributable to a total program, for determination of program cost effectiveness and goal achievement, as part of a broader impact evaluation
- To determine whether savings are persisting as anticipated, as part of retro-commissioning or a vendor's continuing service to a customer
- To demonstrate savings to the end-use customer at different times, establish customer confidence, and maintain customer engagement
- To understand detailed performance characteristics of a particular technology or complex installation, in a range of conditions, as part of technology development or demonstration

In addition to the use of M&V as the basis for contract payments or compliance, M&V can help improve project and program performance in a variety of ways by providing:

- Early feedback on individual projects to the end user and service provider to ensure and improve project performance
- Early feedback on program implementation to correct problems at the project or program level
- Increased customer engagement with programs or private service providers

All of these uses of M&V are enhanced by more timely or more granular feedback. These applications and uses of M&V help determine various attributes for determining savings, such as the baseline conditions, operating conditions, savings calculations, and whether program attribution will be assessed. These applications are important to understanding when and how to apply advanced M&V 2.0 tools with different capabilities.

# 02 ADVANCED M&V METHODS

# ADVANCED M&V METHODS

As noted, emerging M&V 2.0 technologies are affecting M&V in two important ways: (1) increasing the granularity of available data, primarily in terms of finer time scales, and (2) enabling the processing of large volumes of data at high speed, via automated analytics.

## GRANULARITY

New information and communications technologies (ICTs) providing hourly (or even more granular) energy usage data are enabling the reporting of energy use in buildings in near-real time. The increasing prevalence of ICTs—including (but not limited to) high-resolution smart meters, communicating smart thermostats, and nonintrusive load-submetering devices—combined with rapidly falling metering prices are changing the way energy efficiency projects and programs are measured. Availability of hourly data allows more granular analytic approaches that can estimate impacts by time of day.

## AUTOMATED ANALYSIS

Emerging, often cloud-based, software can use improved data access and advanced analytics to automate and accelerate the M&V process. These tools are advancing M&V by enabling ongoing monitoring and estimating of energy savings in near-real time, both for individual premises and for portfolios of homes or businesses.

Together with higher resolution data and multiparameter models, these methods can capture the impact of efficiency on building load shape more accurately. These approaches are intended to be conducted more quickly, more accurately, at lower cost, and with greater value than nonautomated methods. The ability of such tools to deliver these benefits is still being explored, debated, and developed. Such benefits would accrue to various stakeholders across the commercial and residential sectors, including program administrators, third-party evaluators, facility owners and operators, M&V service providers, and regulators.

## STAKEHOLDER BENEFITS OF M&V 2.0

The potential value of applying advanced M&V methods varies across different application contexts, objectives, and stakeholders. We focus here on two key opportunities in the current paradigm that M&V 2.0 is attempting to address:

1. Increasing timeliness (speed to providing insights), by automating the data collection and analysis process to provide near-real time savings estimates; and

2. Using interval data to improve the granularity of analysis to provide more actionable insights for individual energy efficiency projects (e.g., by enabling time-of-day savings estimates) in order to improve the management, implementation, and design of energy efficiency programs.

In the context of energy efficiency programs, EM&V activities often do not start until there is a substantial amount of program activity, with final evaluated savings for a program cycle available only several months after it closes. The time lag between program implementation and evaluation limits both the use of savings estimates to inform potential changes to program design and the ability to make timely performance-based payments to contractors and aggregators. Advanced M&V can alleviate this problem by enabling savings forecasts from a partial post-treatment period. This can accelerate program feedback, and if all parties are willing to base initial payment on a potentially less accurate early measurement, may also allow for a smaller final reconciliation and accelerated financial settlement.

Furthermore, many evaluations lack sufficient granularity in savings estimates to provide actionable feedback to program administrators and other stakeholders. For example, typical sample sizes limit the amount of valuable feedback on the performance of measures, contractors, and other variables. With respect to estimating demand savings, there is often a considerable lack of insight into the time-of-day or grid-level location of savings that can be used for demand response, transmission, and distribution planning. The application of M&V 2.0 techniques offers the dual promise of accelerating evaluation processes and providing more detailed evaluation and implementation feedback. These two critical features of M&V 2.0—speed and granularity—have the potential to provide a range of benefits for key stakeholders:

- ***Program administrators (PAs)***, including utilities, can use early feedback to adjust program designs and budgets more quickly. They can get this early feedback by automating the delivery of usage data and by using advanced analytics to estimate savings with less post-treatment data than is typically used. Among the most important potential benefits of early feedback to PAs are enhanced program targeting (for example, by identifying which types of customers appear to be achieving better measure performance), making adjustments to measure mix (for example, by identifying specific measures that are under- or overperforming), and understanding the effectiveness of specific program implementers and pilot initiatives. Moreover, ongoing program feedback can be communicated internally to management and externally to implementers in the form of "performance dashboards" that can be updated in near-real time. In addition, analysis of hourly or even more granular interval data can inform demand-savings claims and vet specific measures aimed at addressing peak usage and demand.

- ***Program implementers and program energy-efficiency service providers*** can benefit in many of the same ways as program administrators. In addition, early feedback on individual installation performance, particularly with hourly data, enables implementers and service providers to identify and correct operational problems, thereby facilitating improved project performance and higher total savings.

- Similarly, ***energy service companies (ESCOs)[i], contractors, and aggregators*** providing energy

[i] The term ESCO can have multiple meanings in different jurisdictions. In this context, ESCOs are companies engaging in energy savings performance contracts with building and/or building-portfolio owners.

efficiency services outside of programs may benefit from earlier and time-based feedback on savings performance for individual installations. This may help them to identify and correct problems and achieve higher performance payments, where applicable.

- *Third-party evaluators* can benefit by having usage data earlier, which facilitates the ability to provide early indicators of savings and, in some cases, enables them to provide evaluation results more quickly. They also can benefit by being able to provide more granular savings information (for example, by implementer, measure mix, or time of day), thereby providing a more comprehensive understanding of measure impacts or reasons for savings shortfalls. Continuous understanding of program performance can inform evaluation planning, process research, and allocations of scope and budget. Both earlier and deeper feedback (e.g., slicing results by building type, climate zone, substation, installation contractor, measures installed, etc.) would increase the value of evaluation to PAs and their regulators. By automating and, in some cases, accelerating the execution of evaluation, evaluators can also benefit from cost savings.

- *Regulators* serve as stewards of ratepayer dollars and provide oversight to utility energy efficiency programs to ensure cost effectiveness and savings-claims accuracy. To the extent that M&V 2.0 can increase the detail by customer group, reduce evaluation costs, or improve the credibility of the results, regulators will appreciate these benefits.

- ***Grid planners*** can benefit from opportunities created by M&V 2.0 to target and deliver locational and temporal confirmation of energy efficiency impacts. As the industry seeks to increase reliance on energy efficiency as a grid resource, grid planners need to predict short-term demand. They also need reliable savings data for specific hours of the year. Additionally, as grid planners struggle with congestion zones and resiliency issues, interval-level targeting and evaluation represent an important value stream for automated analytics.

- The ***investment community*** seeks to reduce risk in energy efficiency investments since private investment can be hampered by uncertainty in how and when energy savings will be verified. This stakeholder group is looking to M&V 2.0 as a possible avenue to standardize approaches to calculating savings, where applicable. Additionally, investors would welcome accelerated delivery of final savings verification, which could be facilitated through M&V 2.0.

- ***Facility owners and operators*** can benefit by gaining an understanding of how specific interventions affect facility energy use in a near-real time basis, and by receiving early warnings of installation problems so that anticipated savings can be more reliably achieved.

- ***M&V service providers*** can benefit if M&V 2.0 tools provide enhanced capabilities and value, resulting in greater demand for M&V services. M&V models created using daily interval data, instead of monthly billing data, tend to be more robust,[ii] improving their accuracy and the ability to verify the combined savings from new measures and from measures yielding more nominal impacts, such as behavioral changes and operational improvements.

## CAVEATS AND LIMITATIONS OF M&V 2.0

The potential stakeholder benefits of advanced M&V also come with possible trade-offs for many stakeholders.

***Standard practice and code baselines:*** Today's M&V 2.0 tools quantify savings using preinstallation existing conditions baselines. The prior condition may provide a useful baseline for retrocommissioning, whole building/home upgrades, early replacement of functioning equipment (especially "repair indefinitely" equipment), and other behavioral and operational programs, as well as for program and customer feedback. However, there are sound public policy reasons why standard-practice code baselines are used instead of existing conditions baselines for many measure types in most jurisdictions. M&V 2.0 tools may ultimately evolve to estimate a variety of baselines, including standard-practice code baselines, and the outputs may be adjusted to account for standard-practice

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[ii] *Based on Mathieu et al. and Rocky Mountain Institute analysis. The RMI study compared the uncertainty determined for baseline M&V models developed using electric utility data aggregated at hourly, daily, and monthly time periods. Publication pending.*

baselines. However, current M&V 2.0 offerings focus on existing conditions baselines and, as such, are not universally applicable as a basis for all types of program savings.

***Measure-level vs. meter-level savings:*** There are limits to what can be derived from whole-building data, particularly in the nonresidential space. The ability to determine savings for an individual measure or set of measures based on pre- and post-installation whole-building consumption analysis depends on having: (1) a (set of) measure(s) that drives a substantial improvement in a building's total use of each affected energy source, and (2) relative stability in a facility's energy use (outside of the intervention of interest). Engineering calculations, submeter-based approaches, and simulation modeling each attempt to isolate measure-level effects. Alternately, for a relatively homogeneous population, an appropriate comparison group could, in principle, control for the average nonprogram changes. As noted in the Benchmarking and Comparison Testing section, practitioner processes must be developed to ensure that adjustments are appropriately identified and accounted for when changes do occur.

***Data access and quality:*** Data access and quality are critical elements of realizing the benefits of M&V 2.0 and are discussed further in the Standardization section. Although the industry is beginning to make progress to increase data access and improve its quality, stakeholder-specific challenges associated with privacy and ownership, measurement accuracy, and IT infrastructure must be overcome for the full benefit of M&V 2.0 to be realized by all parties, across all applicable use cases.

Although automation suggests the potential for efficiency and cost savings, the impacts resulting from automation must be demonstrated in real-world applications. The Opportunities for Collaboration section highlights pilots as critical to understanding the long-term cost savings that are achievable, and the trade-offs between M&V options, cost and time savings, and resolution and estimation accuracy. The hope is that these methods and tools will facilitate deeper energy efficiency savings and facilitate lower-cost and more-timely time- and place-differentiated insights with an ability to measure savings with greater statistical accuracy.

# 03 AVAILABLE M&V 2.0 TOOLS

# AVAILABLE M&V 2.0 TOOLS

Over the past two to three years, the market has seen a striking increase in the availability of tools that offer M&V 2.0 capabilities. This array of tools can be understood according to five principal distinguishing characteristics:

1. ***Sector focus:*** Tools that offer M&V 2.0 capabilities are designed for use exclusively in commercial, industrial, or residential buildings, or designed for multiple building types. Currently, tools for commercial buildings are most prevalent, followed by those targeted for use in industrial facilities, with some offerings intended for use in both sectors. The number of M&V 2.0 tool offerings for the residential sector is expected to increase in the near future.[iii]

2. ***Primary design intent:*** Many of today's M&V 2.0 tools offer diverse capabilities that extend well beyond M&V, which may not be the primary design intent. A majority of the tools that offer M&V 2.0 for commercial buildings are part of a broader set of tools often referred to as energy management and information systems (EMIS). These technologies include building- and portfolio-level meter analytics and—using supplemental data sources—may also tackle fault detection and diagnostics, and automated HVAC system optimization. Building owners, energy managers, service providers, and program administrators use these technologies to identify opportunities for operational and, sometimes, capital improvement. The technologies commonly offer a combination of automated data analytics, visualization, reporting, and control.

3. ***Degree of automation:*** Across the landscape of M&V 2.0 products, there is a spectrum of the extent to which the M&V is automated. Some products offer fully automated calculations with little ability for users to configure baseline model parameters and form, whereas others may allow a higher degree of user input and more user-defined options. Fully automated tools do not require user expertise in data analysis or modeling; however, that may make it more difficult to add variables or adjust parameters for a more refined result. Conversely, semiautomated tools offer more flexibility, but may not be accessible to all user types interested in tracking energy savings. Fully automated tools are more likely to be delivered as packaged software offerings with continuous data acquisition, higher-end graphics, and operational or other analytics in addition to M&V.

4. ***M&V method:*** M&V 2.0 products use a diversity of M&V methods, or approaches, to calculate savings. For the most part, these methods are implementations of industry-standard approaches (see the M&V Overview section), such as those defined in the IPMVP or those commonly used for evaluating efficiency programs. Tools may differ in whether they describe what they calculate as gross or net savings, in the mathematical form and definition of the baseline that

[iii] *Kupser et al. describes the vendor landscape (at the time of writing) for M&V 2.0 offerings.*

they use to determine savings, in their use of interval versus monthly data, or in their ability to operate on whole-building as well as submetered data. In addition, some tools are programmed to report accuracy metrics such as baseline model goodness-of-fit, or estimations of savings uncertainty.

5. *Transparency:* The majority of tools that offer M&V 2.0 capability are proprietary and unavailable through open-source code licenses. However, a tool developer may offer open documentation of the specific M&V methodology that is implemented even if the code itself is not publicly available, similar to the way the EM&V sector operates today. The degree of specificity varies, and may include method inputs and outputs and analysis approaches or quantitative model definitions. The level and precise form of transparency and standardization that the industry will ultimately require of M&V 2.0 tools is an open issue and an ongoing topic of discussion among stakeholder groups. These issues are further discussed in the Standardization section of this report.

In the rapidly advancing market of energy analytics software tools, new offerings are frequently becoming available, and existing technologies are being improved. Today's market is dominated by proprietary tools that target commercial buildings using IPMVP Option C and, in some cases, Option D. However, the industry is moving to accommodate expanded combinations of the five distinguishing characteristics described above.

# 04 STANDARDIZATION, GUIDELINES, AND PROTOCOLS

# STANDARDIZATION, GUIDELINES, AND PROTOCOLS

An active discussion in the M&V community is the role of standardization of process and methods to support advancements. Formalized standards may be complemented by guidelines and protocols. In this section we discuss key issues and current work related to these topics.

## STANDARDIZATION

Standardization has many benefits. It allows for M&V 2.0 solutions to scale across utilities and uses. It allows for apples-to-apples comparisons of savings estimates produced by different tools. It allows for portfolio analysis across savings assets and drives increased private investment. However, standardization has a drawback: it can stifle innovation of new methods and new use cases that were not available or anticipated during the standard-setting process. If misapplied, standardization can result in the use of methods that are not well suited to particular applications, resulting in reduced accuracy of results. One approach to fostering innovation and customization while allowing for some of the benefits of standardization is to focus on data access, formats, and cleaning, and to enable methodological innovation by standardizing tests that allow for methodological benchmarking and comparisons.

### *Data Access and Confidentiality*

The ability to access utility billing data in a consistent and secure fashion—including interval data—is a significant challenge to the widespread adoption of M&V 2.0 tools and the benefits associated with them. M&V 2.0 tools require, at a minimum, consumption data, project and building characteristics, and weather data. Ideally, access to these data sources should be automated. These requirements give rise to important technical and legal issues of data access, many of which industry and regulatory parties have only begun to tackle.

### *Data Formatting*

The next major challenge to practical use and delivery of M&V 2.0 tools is ensuring a standard data format. Through the Green Button initiative, the U.S. Department of Energy has done formative work in driving industry adoption of some common data formats, and industry-led efforts in data standardization like HP-XML have begun to be adopted, but the industry still needs to invest time and effort into standardizing and adopting data formats.

### *Benchmarking and Comparison Testing*

There is growing industry interest in technology-performance testing procedures that can be used to determine whether a given M&V 2.0 tool or method is robust and well implemented. In response, researchers have developed, applied, and published a test procedure to determine the overall predictive accuracy of M&V 2.0 approaches that are based on IPMVP Option C or Option B.[3] This test procedure is based on large test data sets and makes it possible to evaluate, compare, and contrast both open-source and proprietary M&V 2.0 tools. It has been used by a large utility, and has been replicated by Northwest Energy Efficiency Alliance in an analysis for residential buildings. This procedure is published in the open literature, and industry stakeholders are beginning to consider the need for and value of formalizing and standardizing these tests for ongoing, repeated use.

It is worth noting that comparison testing does not require transparency into the underlying approaches used in the tool; it can be applied to closed proprietary methods as well as to open methods. There is no industry consensus yet as to whether performance-based testing alone will be sufficient to validate a given tool, or whether full transparency of algorithms will be required. We are not aware of test procedures that have been developed to evaluate the performance of tools that rely on other common M&V approaches (such as comparison group analyses) or other methods that address baselines other than existing ones. This is an area of high interest and anticipated future work.

## CURRENT STANDARDIZATION WORK

### *ACCA BPI*

The Air Conditioning Contractors of America (ACCA) and the Building Performance Institute (BPI) have formed a joint Standards Development Committee to create a “Protocol for Quantifying Energy Efficiency Savings in Residential Buildings.” The current scope of the standard is described by the cochair of the working group as follows:

> This standard provides replicable calculation procedures for quantifying energy savings in existing homes utilizing weather-adjusted metered data, and for aggregating impacts to increase confidence in savings that result from energy interventions or programs. Outputs may include energy impacts (MMBtu, kWh, therms), demand impacts (kW), time, locations, and seasonality of savings.[5]

The standard applies primarily to the use of weather-normalized, pre- and post-installation changes in consumption as the definition of savings. The committee is working to create an initial draft of the standard for public comment.

### *CalTRACK*

The California Energy Commission and the California Public Utilities Commission have undertaken an effort to enable a standard, statewide protocol to measure savings delivered from residential whole-house energy efficiency upgrades. Called CalTRACK, this protocol will provide a common framework for tools developed for measuring gross energy savings. The CalTRACK protocol will serve as a basis for estimating initial performance payments by Pacific Gas and Electric Company’s new residential pay-for-performance “whole house” program in California. An important aspect of the CalTRACK development process has been the work of an open, multi-stakeholder technical working group to develop and empirically test a set of technical and methodological requirements for the CalTRACK protocol that is vendor agnostic.

### *Uniform Methods Project (UMP)*

The U.S. Department of Energy has been leading the development of a standardized set of M&V protocols. The protocols cover the most commonly implemented energy efficiency programs and measures, which account for the vast majority of savings from customer-funded programs. Each M&V protocol is measure specific, has defined application conditions, and focuses on gross savings (exceptions apply). Each measure's protocol was developed by a group of experts, with a robust stakeholder process. Included in the UMP are utility billing-based analysis procedures for whole house, commercial whole building, and retrocommissioning applications.

### *ASHRAE Guideline 14*

The American Society of Heating Ventilation and Air-Conditioning Engineers (ASHRAE) Guideline 14-2014 outlines procedures that define minimum acceptable approaches for determining energy and demand savings using measurements in commercial transactions. One method involves measuring post-retrofit energy use and comparing that to pre-retrofit use, adjusted to post-retrofit conditions using a baseline regression model. Guidance is provided for assessing baseline model fitness and savings uncertainty due to model error. The uncertainty formulations in Guideline 14 are approximations that are most accurate for purely linear models without a high degree of serial correlation, and uncertainty quantification is a topic of growing industry focus and ongoing work.

### *Efficiency Valuation Organization (EVO)*

The Efficiency Valuation Organization (developer and owner of the IPMVP) maintains documents that provide the core concepts of M&V along with application guidelines. EVO plans to update content to include advanced M&V considerations with each publication cycle. Soon to be released by EVO is the 2017 Statistics and Uncertainty Application Guide. This guide will expand upon the materials published in Guideline 14-2014 and will clarify the limitations associated with applying statistical methods developed for linear models to interval-data applications. As noted above, the industry continues to investigate the best approach for aggregating the uncertainties of the adjusted baseline estimation to determine the uncertainty of the final savings estimate.

## CURRENT CHALLENGES

While many of the applications discussed in this paper are being tested or are fully deployed in the field, much of the promise of M&V 2.0 laid out in this paper's introduction has yet to be fully realized. Unresolved technical, methodological, regulatory, and business-model challenges remain, and opportunities for innovation still exist. Some of these challenges and opportunities include:

- Data sources and access
  - Simplified data transfer authorization, exchange, and interoperability through more ubiquitous adoption of Green Button connect, HP-XML, building button, and other API-based access methods by equipment manufacturers
  - Integration of metering and solar-generation data access
- Data integration and cleaning
  - Improved record linkage through more standard data cleaning and data quality procedures, public universal site IDs, and enhanced utility account-level practices

- Savings estimation and aggregation
  - Methods for predicting baseline electricity usage can be improved beyond current practice
  - Methods for higher-resolution metering of gas and water consumption remain underdeveloped in today's applications
  - Methods for combining generation and load data at the site level
  - Methods for combining non-meter event data from devices and behavioral programs (smart thermostats, text messages, etc.) are increasingly important as programs diversify
  - Methods for improving matching, automated comparison group construction, and synthetic control generation
  - Methods for estimating uncertainty consistently and comparably across the diversity of higher-resolution methods
- Challenges to reporting and anonymization
  - The secure, anonymized publishing of savings results for demonstrating savings yield and demand capacity
- Policy challenges
  - Approval and encouragement by regulatory commissions for piloting and using M&V 2.0 methods and estimated quantities for a broader set of use cases (including pay-for-performance, procurement, and claimable savings)
  - Regulatory innovation in allowing for M&V 2.0 methods to reduce costs throughout the energy efficiency value chain, especially in reducing EM&V costs
  - Improvement and standardization in guidelines and policies across regions to allow for M&V 2.0 uses
- Business model challenges
  - Diversified solutions for efficiency service providers to incorporate delivered savings into their business models and to manage measured savings risks

# 05 KEY NEEDS AND OPPORTUNITIES

# KEY NEEDS AND OPPORTUNITIES

If industry is to realize the great promise of M&V 2.0, it must address a set of critical interrelated needs.

***Pilots:*** To date the number of publicly available case studies or research reports that document the use of M&V 2.0 tools for savings estimation is limited. What's more, it is difficult to synthesize the information currently in the public domain to understand whether, where, and to what extent the expected benefits of M&V 2.0 are realized. For example, how does more-timely continuous savings feedback impact savings realization and customer experience? What types of facilities and measures do M&V 2.0 tools work well for, and where is additional human expertise required? What are the trade-offs between time, cost, and accuracy? There is immediate opportunity for all M&V stakeholders to design, conduct, and review the outcomes of pilots to effectively address industry's open questions.

***Practitioner workflows:*** As the industry becomes increasingly able to routinely test and vet the underlying technical methods of M&V 2.0 tools, it will be necessary to determine how these tools can be integrated into practitioners' professional workflows, given the need to ensure high accuracy in savings estimates. Practitioner processes must be developed that can use the benefits of automation while still addressing issues such as: how to determine which buildings or programs are well suited to more automated treatment; how to apply analytics to flag the potential need for nonroutine adjustments (see the Caveats and Limitations section);[iv] what data will support more consistency and rigor in quantifying adjustments; how and where to cost-effectively integrate additional data from building automation system trend logs; and whether reporting savings uncertainty due to the error in the baseline model will serve as a useful quantitative indication of the quality of the savings result. Evaluators, implementers, and utility program administrators have the opportunity to work with the vendor and research community to establish these workflows, and test and apply them in M&V 2.0 pilots.

***Acceptance criteria:*** As industry becomes more interested in testing, piloting, and validating M&V 2.0 tools, there is a growing need to establish collective acceptance criteria. These may relate to accuracy, uncertainty, and confidence, as well as documentation and reporting of results. In the intermediate term, regulators, evaluators, and regional efficiency organizations (REEOs) have the opportunity to collaborate with other subject matter experts to determine where to set the bar for rigor that M&V 2.0 tools and their application must meet.

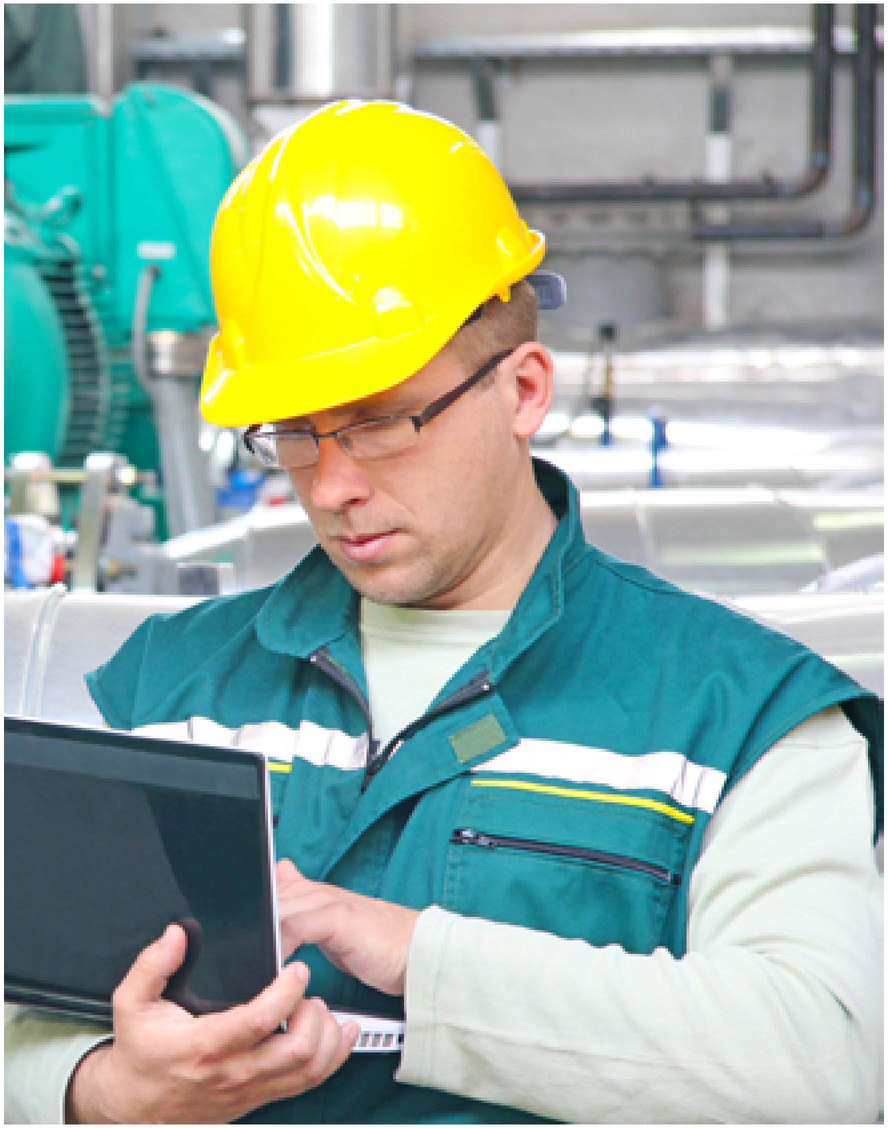
***Data access and availability:*** Closely related to the topic of practitioner workflows are practical needs associated with data access, availability, and quality. The benefits of M&V 2.0

[iv] *Nonroutine adjustments may be necessary to associate meter-level savings with measure-level energy savings. (Adjustments are detailed in Efficiency Valuation Organization, International Performance Measurement and Verification Protocol)*

are rooted in the power of computation and analytics when combined with increased data availability. As such, as the industry is able to address these needs, the benefits of M&V 2.0 may grow. Over the long term, the regulatory community, standardization bodies, technology vendors, and agencies working for the public benefit will have a role in continued collaboration to realize the promise of data for building energy efficiency, including but not limited to M&V 2.0.

*Treatment of additional baselines:* As the M&V 2.0 tools industry looks to expand the number and type of efficiency programs in which they can be applied, it may consider the value of expanding its solutions to be able to treat baselines other than existing conditions. There is opportunity for M&V 2.0 developers to enhance their offerings to include standard practice and potentially to code baselines in addition to existing conditions.

*Peer learning and information sharing:* The M&V 2.0 landscape is quickly evolving, with parallel dialogues occurring across professional organizations, regional forums, conferences, and workshops. Often, and for good reason, these conversations either occur within a single stakeholder group, or relative to a specific use case or regional issue. There is, however, ongoing opportunity for cross-stakeholder groups to coordinate for enhanced peer learning and information sharing. REEOs and state efficiency organizations, cross-disciplinary conferences, and the research community are particularly well suited to facilitate these groups.



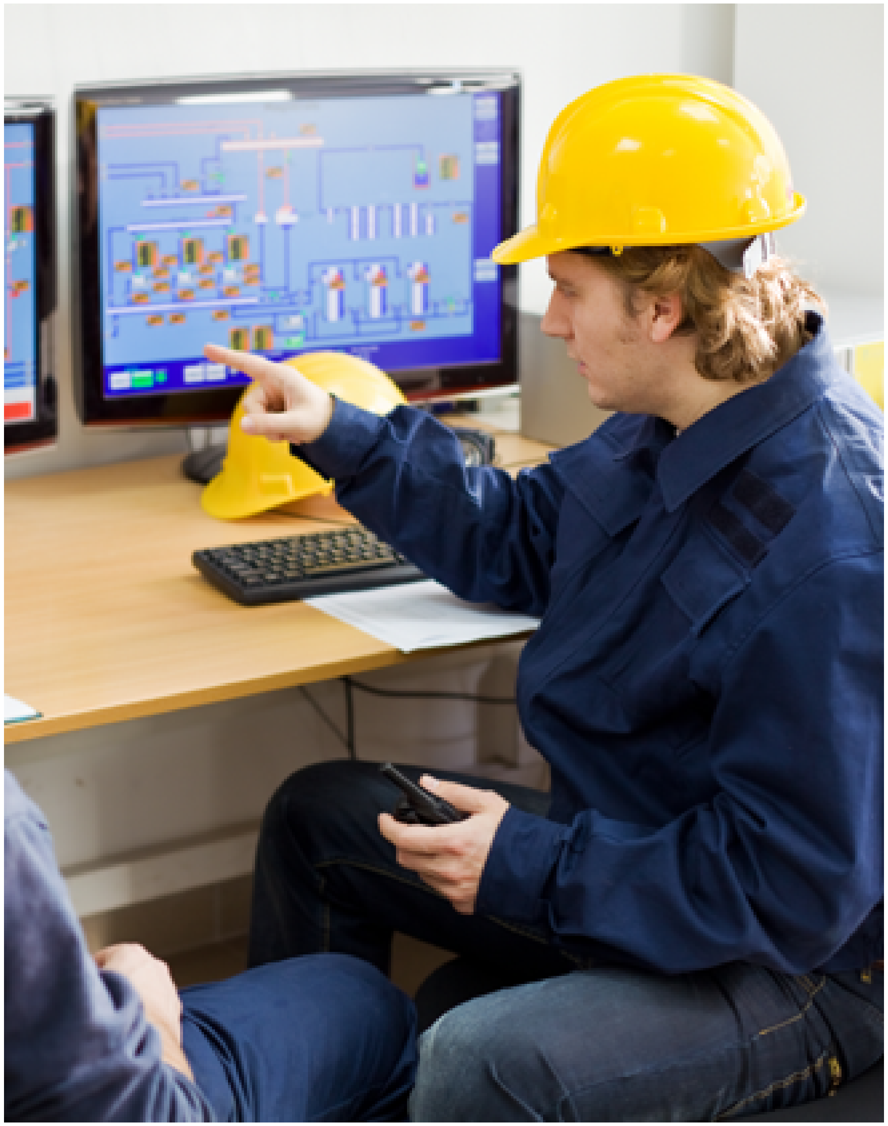
# 06 CONCLUSIONS

# CONCLUSIONS

When its full potential is realized, M&V 2.0 applies analytics to large volumes of time-differentiated energy usage data to value the impact of building efficiency projects. Advanced M&V methods use the increased availability of utility billing-quality interval data and the ability to quickly process large amounts of data using automated analytics. With the use of new technologies, savings can be determined in near-real time to benefit a range of stakeholders and provide a baseline consistency across applications.

Understanding the different purposes for measuring savings is important for assessing the value of advanced M&V 2.0 tools with different capabilities. The capabilities of existing tools can be categorized according to five principal distinguishing characteristics: sector focus, primary design intent, level of automation, M&V method, and analytic transparency. Tools with new capabilities are continually becoming available. General methodologies are being developed to evaluate software capabilities by evaluating model performance and prediction accuracy. The development of other standards is supporting advancement, such as those that address data access and confidentiality issues.

These efforts hold great promise for facilitating deeper energy efficiency savings through better customer engagement, program optimization, and potentially increased accuracy and certainty in savings determination. Increased accuracy, certainty, and standardization of savings calculations could support increased energy efficiency activity not only through



individual building initiatives and programs, but also through new markets for tradable energy efficiency savings.

However, trade-offs that apply across many stakeholders exist. Specifically, current offerings focus on savings relative to existing conditions, and therefore are not universally applicable as a basis for all types of program savings. The methods rely on having multiple-measure whole-building interventions or measures having a likelihood of large impacts on total facility energy consumption and relatively little change at the facility (outside the intervention of interest) between pre- and post-intervention periods. Practitioner processes must be developed to ensure that adjustments are appropriately identified and accounted for when changes occur. Data access and quality are critical elements for realizing the benefits of M&V 2.0. Although the industry is beginning to make progress, stakeholder-specific challenges associated with privacy and ownership, measurement accuracy, and IT infrastructure must be overcome for the full benefit of M&V 2.0 to be realized by all parties, across all applicable use cases.

Several opportunities exist for key stakeholders to collaborate to move efforts forward. Key industry needs for M&V 2.0 to realize its full promise include the following:

- Conduct pilots and provide public-domain information on the results to understand whether, where, and to what extent key expected benefits of M&V 2.0 are realized.
- Establish how to integrate M&V tools into practitioners' professional workflows.
- Establish collective acceptance criteria related to accuracy, uncertainty, and confidence, as well as documentation and reporting of results.
- Establish guidelines and best practices related to data access, availability, and quality.
- Establish guidelines and best practices related to standardization and testing.
- Explore the value and feasibility of expanding M&V 2.0 solutions to treat baselines other than existing conditions.
- Establish cross-stakeholder groups to coordinate enhanced peer learning and information sharing related to M&V 2.0.

# 07 ENDNOTES

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315 +8.14%
167 +4.19%
170 -7.55%
141 +1.2%
104 +8.47%
35 +1.56%
15 +1.73%

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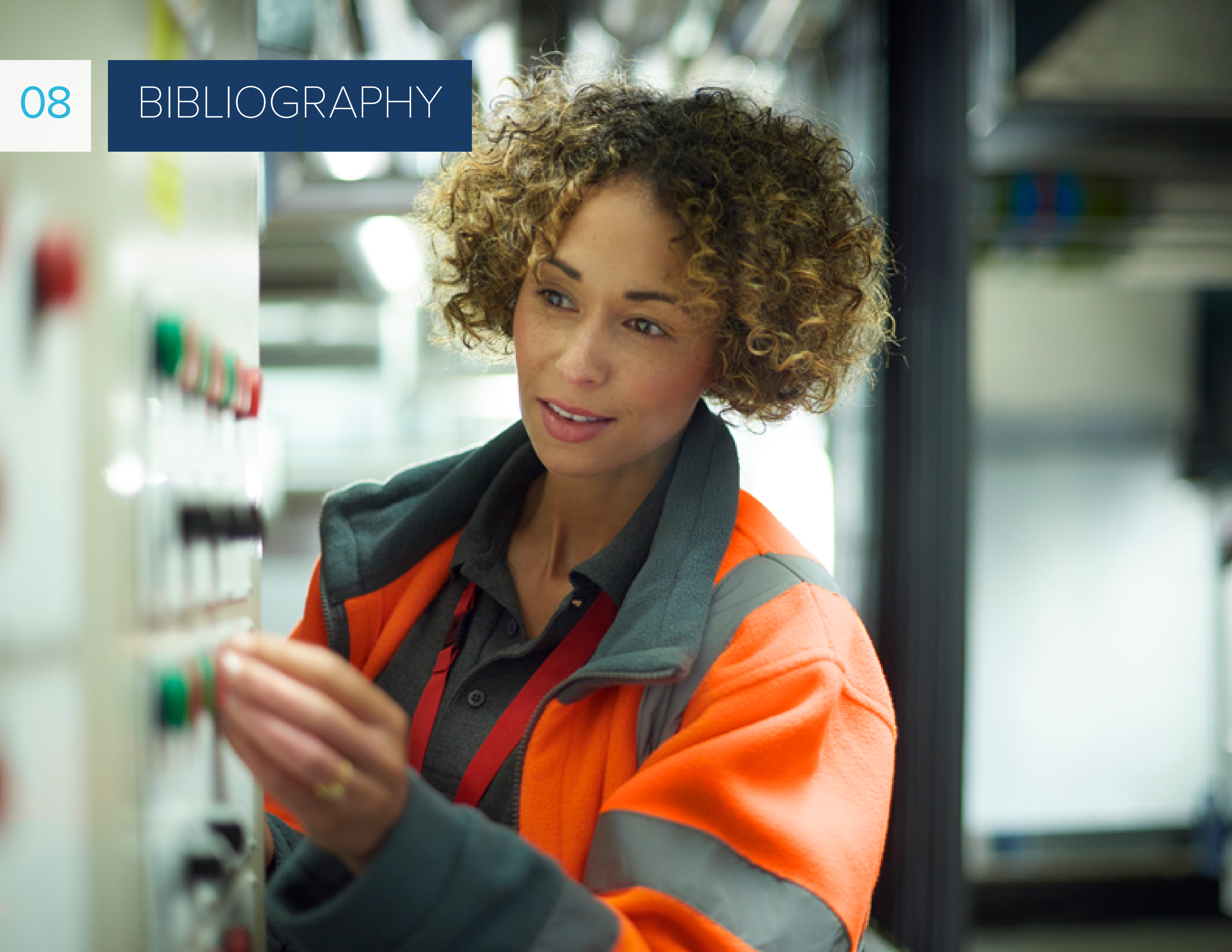

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