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Low-cost M&V options

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Learning objectives

Understand when to use operational verification vs. complete M&V.

Understand different types of low-cost M&V methods and tools.

Illustrate low-cost methods and tools with real-world examples.

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Abbreviations

Acronym	Meaning
ASHRAE	American Society of Heating Refrigeration and Air Conditioning Engineers
BAS	Building Automation System
CDD	Cooling Degree Days
CMVP	Certified Measurement and Verification Professional
Cv(RMSE)	Coefficient of Variation of Root Mean Square Error
EEM	Energy Efficiency Measure
EMIS	Energy Management Information System
EVO	Efficiency Valuation Organization
GJ	Gigajoule
HDD	Heating Degree Days
IPMVP	International Performance Measurement and Verification Protocol
HVAC	Heating, Ventilation and Air Conditioning
kW	kilowatt(s)
kWh	kilowatt-hour(s)
M&V	Measurement & Verification
PMVA	Performance M&V Analyst

Today's agenda

1. The cost of doing or not doing M&V
2. Operational verification
3. Retrofit isolation: option A, sampling, BAS/EMIS
4. Whole facility (option C)
5. Low-cost metering tips
6. Summary

The cost of doing or not doing M&V

Reminder: the advantages of M&V

Without M&V

- No additional cost
- Energy savings are not verified

With M&V

- Energy savings are maximized
- Energy savings persist

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M&V and costs

The M&V costs must be aligned with the anticipated variations within the measurement boundary and the expected savings.

The M&V costs should be relatively small compared with the expected monetary savings.

M&V and costs

The cost of determining savings using the measurement and verification method depends on many factors.

- The IPMVP option selected and measurement boundary used.
- The number of measures and their complexity.
- Funding stakeholders' required accuracy in reported savings.
- The level of effort associated with the approach selected.
- The operational verification activities required for each measure.

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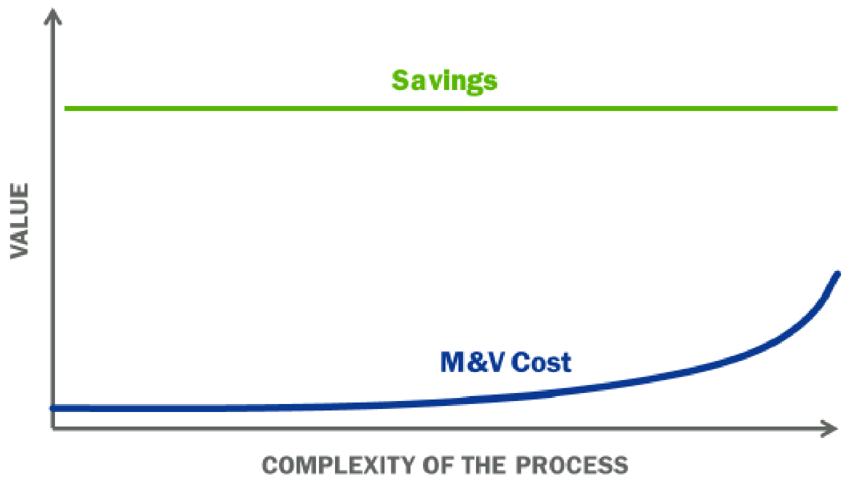
M&V and costs

A best practice is to minimize the cost associated with data collection and analysis in relation to the expected **economic benefit**.

Rule of thumb: the average M&V costs should be **less than 10%** of the annual cost savings of the project.



(IPMVP Core Concepts, EVO 10000 – 1:2022)

Important steps when conducting M&V

Even with low-cost M&V, these items **must** be documented:

- Reasons for investing in M&V
- EEM system description and measurement boundary
- Key variables that might be needed for adjustments
- Lead M&V professional for the project
- Specific variable(s) to be metered
- Site verification
- Analysis description and methodology
- Reporting: who, how, when

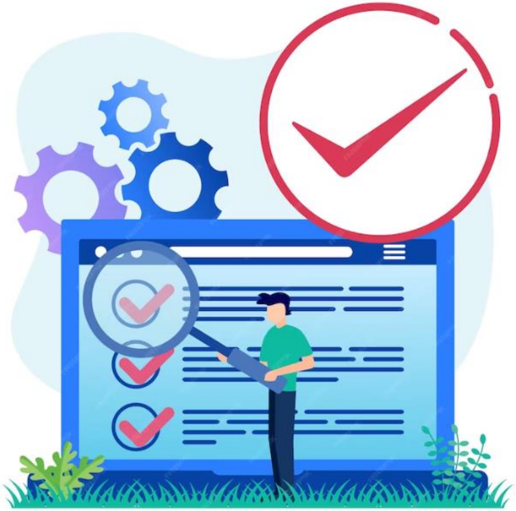
Operational verification:

The “V” in M&V

Definition

"Operational verification consists of a set activities intended to ensure that the measure is installed, commissioned, and performing its intended function. Confirmation that Energy Efficiency Measures are installed and operating as per the design intent and have the potential to perform and generate savings is required."

Source: International Performance Measurement and Verification Protocol (IPMVP), CORE CONCEPTS 2022



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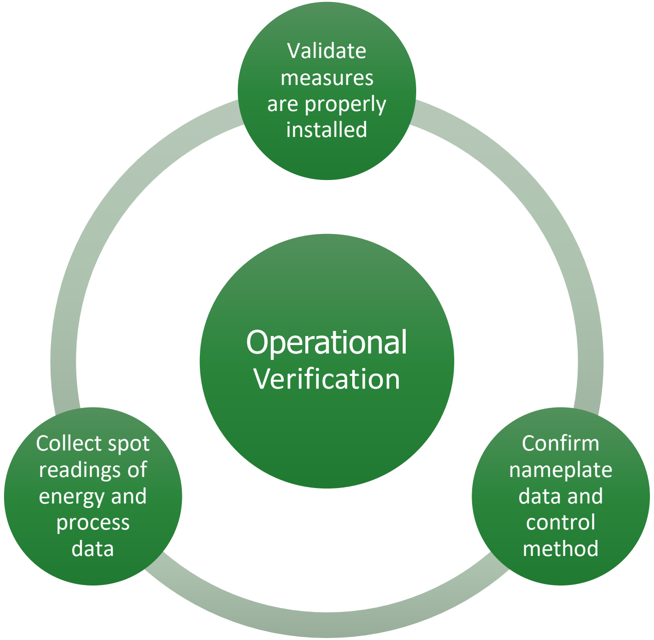
Operational verification



Operational verification can serve as a **low-cost procedure** for **assessing savings potential** and the selection of the best approach to operational verification depends on:

- Equipment characteristics: real-world experience reveals that field changes to design/bid specifications are common.
- Accuracy required
- Magnitude of the savings

Reminder: <u>always</u> justify your assumptions in engineering calculations!

When to opt for operational verification *only*?

- When there is little doubt about the outcome of the project.
- When there is no need to prove results to a third party.
- For relatively small projects involving small savings.

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Operational verification approaches

Visual Inspection	Sample Spot Measurements	Short-Term Performance Testing	Data Trending and Control-Logic Review
• View and verify the physical installation of the measure.	• Measure single or multiple key parameters for a representative sample of the project.	• Test for functionality and proper control. • Conduct functional tests to capture the component or system operating over its full range of performance.	• Set up trends and review data or control logic. • Measurement period may last for a few days to a few months, depending on need to capture the full range of performance.

Examples of operational verification

Lighting system upgrade	HVAC system optimization	Water conservation measures
• Confirm that the lighting fixtures, such as LED bulbs are installed according to specifications. • Verify the lighting controls (sensors, timers) are calibrated and functioning correctly.	• Check that the upgraded HVAC systems, such as high-efficiency units, are installed and configured properly. • Verify the temperature setpoints and scheduling are aligned with energy-saving goals.	• Confirm that water-saving devices (low-flow faucets, efficient irrigation systems) are installed and functioning. • Monitor water consumption patterns and compare them with the baseline data.

Example: operational verification template

Operational Verification Form

Organization Name – Project Name		Site Visit Date (yyyy – mm – dd)
Building & Project	xxxxxx building name and building identifier	xxxxxx address
Site Inspection Completed by*	xxxxxx name	xxxxxx department or company
Site Contact	xxxxxx name	xxxxxx department or company

Site safety check-in. List safety requirements such as personal protective equipment, roof access, electric measurements, etc.	list key safety requirements here

Operational Verification Form

List EEMs and Key Equipment prior to site visit		**EEM status, equipment tag #, &/or other site notes (fill out on site)**	**Check all that apply**
Energy Efficiency Measure (EEM)	Key Equipment to inspect		
EEM1	VFDs on AHU-10 and AHU-11		☐ Verified installed & in operation ☐ Control Logic reviewed (BAS** printout) ☐ Photos (e.g. nameplate, local display) ☐ Operating schedule confirmed ☐ Spot readings recorded ☐ Data trending confirmed ☐ Performance testing completed ☐ Reports (e.g. commissioning, balancing)
EEM2	Convert parkade lighting to LED		☐ Verified installed & in operation ☐ Control Logic reviewed (BAS** printout) ☐ Photos (e.g. nameplate, local display) ☐ Operating schedule confirmed ☐ Spot readings recorded ☐ Data trending confirmed ☐ Performance testing completed ☐ Reports (e.g. commissioning, balancing)

Retrofit Isolation

Option A (key measurements)
Sampling
BAS or EMIS data

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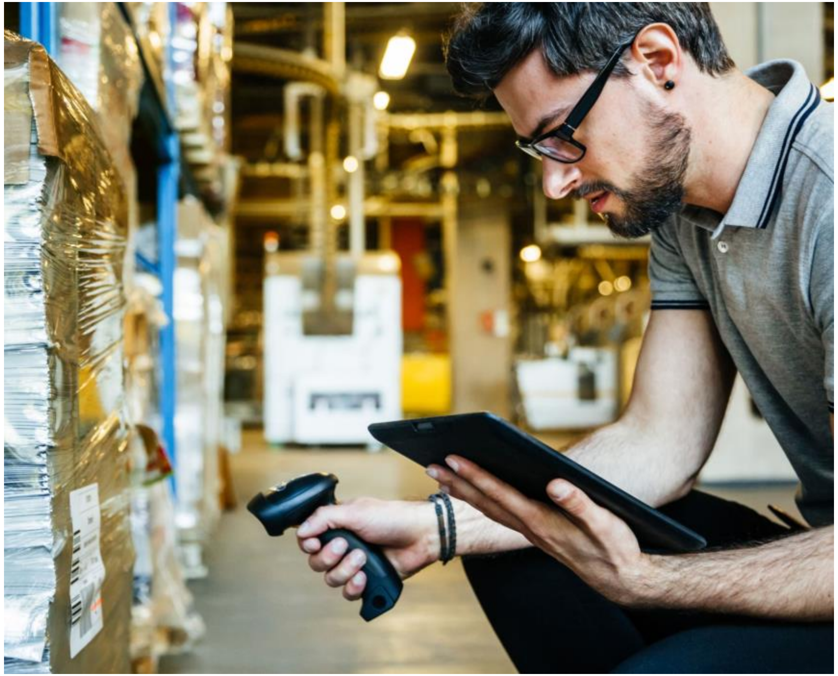
IPMVP option A: measure at least one key parameter

Key parameter:

"Critical variable(s) identified to have a significant impact on the energy savings associated with installing an Energy Efficiency Measure."

Source: International Performance Measurement and Verification Protocol (IPMVP), CORE CONCEPTS 2022



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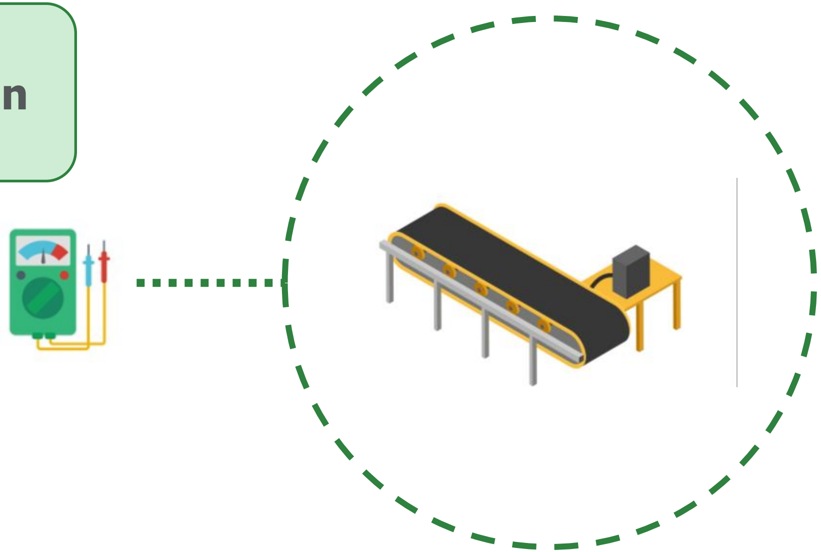
Measurement boundary and key parameters

What influences your energy consumption?

Occupation

Weather



Production volume

Key parameter measurement (IPMVP option A)

The key parameter measurement methodology is a combination of **measurement of key parameters** and stipulation of other, less important parameters.

The measurement period depends on the **load variability** (from a few hours to a few days).

Always conduct measurements **before <u>and</u> after** measure installation.

Example of a motor's key parameter: power at full load **<u>or</u>** runtime.

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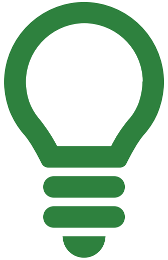
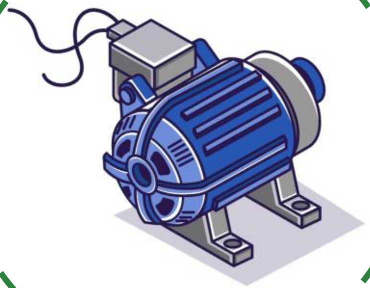
Examples of key parameters

Electric power





Bulb wattage

Hours of operation

Pump flow

Hours of operation

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Example of a key parameter measurement approach

Lighting replacement project

A production plant is retrofitting 1,000 fluorescent lamps to 100 LEDs, the average lighting schedule is 10 hours a day for 350 day a year.

- **Key parameter:** Lamp wattage
- **Stipulated parameter:** Hours of operations (source: based on facility schedule)

Results

The power of the equipment is measured **before** and **after**:

- Before: Average wattage = 31 W/lamp
- After: Average wattage: 15 W/lamp
- Annual energy savings = (31-15)W x 1,000 lamps x (10 x 350) hours / 1,000 (kW/W) = **56,000 kWh**

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Example: lighting M&V template

- This Save on Energy M&V plan template is specific to lighting projects that have opted to use an IPMVP option A M&V approach.
- The template will be available on the Save on Energy website in the near future.

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M&V PLAN TEMPLATE

Lighting Project

1. Project Description and Methodology

Project description — *What is the project?*

In describing the project, it can be helpful to include the existing conditions as a reference, what is being installed or changed, the quantities involved, and any additions or controls included in the project. You can use a table such as below, create multiple tables if needed, or import a description from another file.
Often existing and baseline are the same. In some cases, the baseline equipment and/or operating conditions could be different than existing. Existing and baseline may differ when existing equipment is not meeting current service needs, or the service needs are changing (e.g. facility change of use or occupancy schedules). Example: baseline consists of a standard lighting remodel due to a change in occupancy, while the project is to invest in more efficient LED lighting.

	Baseline Equipment and Operating Conditions	Project Equipment and Operating Conditions
Lighting type	*Fluorescent*	*LED*
Wattage per fixture/lamp	*32*	*15*
Quantity of fixtures/lamps	*1000*	*900*
Operating hours	*2000*	*1500*
Controls	*Schedule*	*Schedule + daylight sensor*
Other		

Measurement Boundary — *What is measured and where? For how long?*

documented.
State whether interactive effects may apply, and if the M&V will quanitify interactions (e.g. upgrade to more efficient lighting may increase load on space heating system in winter, and decrease load on space cooling in summer).

Sampling approach used?	*Yes/No; if yes, specify how many measurements will be taken.* *To decide on sampling, consider whether you have:* *(1) a large quantity of equipments in your project, or* *(2) if the equipment operates on a wide range of parameters (e.g., temperature)*
Impact on other fuels?	*If the project's objective is to save electricity, will the project substantially impact (increase or decrease) other energy forms purchased by the facility such as natural gas or biofuels? If so, the M&V plan should address how these impacts will be measured or estimated.*

Measured Values	Baseline Conditions	Project
Operating hours	*Measured; for one week*	*Measured; for one week*

Note: more than one parameter can be measured (wattage and operating hours); this is just an example. Refer to specific program requirements if you are applying for incentive.

What are the assumptions (values that are used but not measured)? Indicate the source of each assumption.

Estimated or Stipulated Values	Baseline Conditions	Project
This will allow a third party to follow your thought process.		
Wattage	*Stipulated (source: nameplate data)*	*Stipulated (source: DLC listing)*

Retrofit isolation with **sampling** reduces M&V cost

- Industrial example:
  - 47 end uses, motor driven
  - Sampling: 12 motors

Table 3.1 Equipment List

Drive Location / Description	Nameplate hp	Number of Units / Motors	Number of Motors Metered for M&V	M&V Strata Group Number
AUTO ROTATE CONVEYOR (IPM)	50	1	1	Group One
LOG TURNER, QUAD ROLL (LH / RH)	7.5	2	1	Group One
POSITIONING INFEED CENTERING ROLLS #1	5	2		
POSITIONING INFEED CENTERING ROLLS #2	5	2		
POSITIONING INFEED SPIKE ROLLS (LH&RH)	5	2		
SIDE HEAD (LH)	200	1	1	Group Three
SIDE HEAD (RH)	200	1	1	Group Three
VFM (LH&RH SIDE)	7.5	2		
VFM (LH&RH SIDE)	7.5	2		
POSITIONING INFEED SHARP CHAIN (IPM)	20	1	1	Group One
CHIPPED FACE TRANSPORT CHAIN	20	1		
TOP HEAD	200	1	1	Group Three
BOTTOM HEAD	200	1	1	Group Three
QASB #1 VFM-FEED ROLLS (LH&RH SIDE)	7.5	2		
QASB #2 VFM-FEED ROLLS (LH&RH SIDE)	7.5	2		
QASB #1 FEEDROLLS	10	1		
QASB #2 FEEDROLLS	10	1		
SIDEBOARD SEPARATOR O/F #1-ENCODER	20	1		
SIDEBOARD SEPARATOR O/F #2-ENCODER	20	1		
CENTERING ROLLS (LH&RH SIDE)	5	4		
VFM	7.5	2		
QASB #1 and #2 PRESSROLL	10	2	1	Group One
QASB #1 PROFILER TOP (LH / RH SIDE)	100	2	1	Group Two
QASB #1 PROFILER BOTTOM (LH / RH SIDE)	100	2	1	Group Two
VDAG PROFILER TOP (LH / RH SIDE)	100	2	1	Group Two
VDAG PROFILER BOTTOM (LH / RH SIDE)	100	2	1	Group Two
VDAG INFEED ROLLS	10	2		
VDAG OUTFEED ROLLS	10	2		
		47 total		

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Retrofit isolation with **sampling** reduces M&V cost

- Industrial example:
  - End uses disaggregated into three groups
  - Used Bonneville Power Authority resources for sampling plan

$$Post\ retrofit\ Energy, kWh/yr = \sum_{Groups} \frac{Total\ namplate\ HP}{Sampled\ nameplate\ HP} (Sampled\ motors\ energy, kWh/yr)$$

$$Baseline\ Energy, kWh/yr = \sum_{Groups} \frac{Post\ retrofit\ Energy, kWh/yr}{(1 - \%\ savings\ )}$$

% savings for each group was equal to the annual percentage of energy savings from the IR, using the following stipulated values:

Group One % savings = 44.9%

Group Two % savings = 13.3%

Group Three % savings = 16.4%


BONNEVILLE POWER ADMINISTRATION

Sampling for M&V: Reference Guide

July 2018

Source: www.bpa.gov/energy-and-services/efficiency/measurement-and-verification

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Retrofit isolation with **sampling** reduces M&V cost

Other common applications for M&V sampling include:

- Multiple air-handling units
- Lighting upgrades

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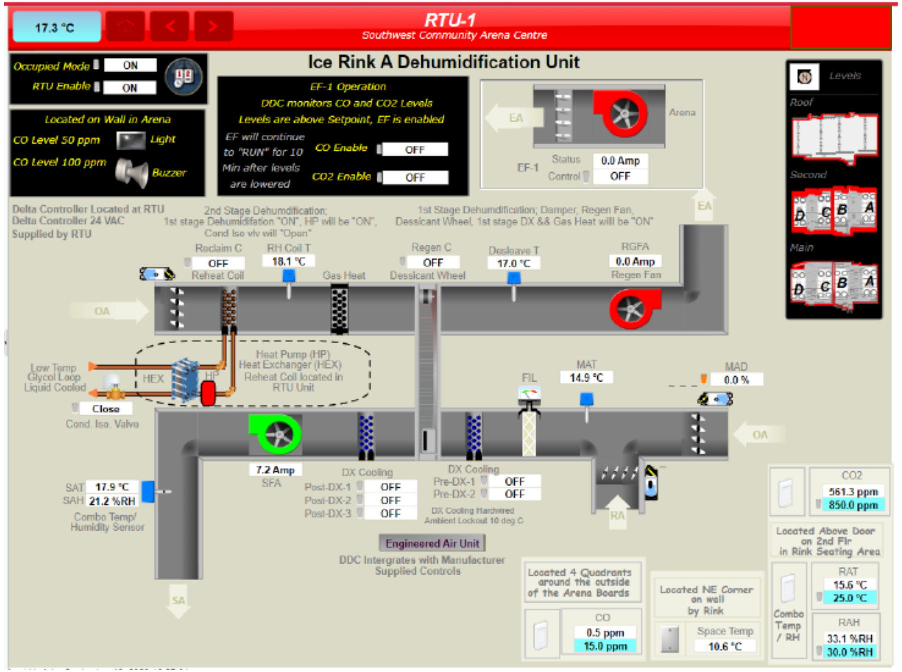
Using BAS/EMIS data for low-cost M&V

Example:

- Kaizen™ EMIS enteliWEB™ BAS



Note that many other EMIS and BAS systems are commercially available

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Using BAS/EMIS data for low-cost M&V

- Sample calculations can be done using BAS data

					nameplate HP (or kW)	0.75 hp	
					~ max input kW	0.589	
					~ max input kWh/day	14.13	
				min →	-194,491.76	0.00	0.00
				max →	194,491.76	14.40	14.40
				avg →	1.70	6.29	8.98
AHU Heating Pumps Logic Flow-P1106 KWH CTL	Boiler Pumps Logic Flows-PP1102 KWH CTL	AHU Heating Pumps Logic Flow-P1107 KWH CTL	AHU Heating Pumps Logic Flow-P2101 KWH CTL	Timestamp	AHU Heating Pumps Logic Flow-P2102 KWH CTL	Boiler Pumps Logic Flows-PP1101 KWH CTL	Boiler Pumps Logic Flows-PP1104 KWH CTL
127732.7958	6310.35	131437.3968	202980.828	2022-Jan-01			
128068.7148	6324.15	131779.2736	202980.828	2022-Jan-02	433.84	14.40	0.00
128420.9758	6337.5	132137.7842	202980.828	2022-Jan-03	453.96	14.40	7.80
128781.3863	6350.85	132504.7503	203250.2865	2022-Jan-04	168.97	14.40	11.40
129127.2604	6365.25	132856.9208	203690.6291	2022-Jan-05	0.00	14.40	12.75
129486.6616	6379.65	133222.5492	204133.0301	2022-Jan-06	0.00	14.40	11.85
129823.9762	6394.05	133565.9876	204565.3354	2022-Jan-07	0.00	14.40	10.35
130176.8712	6408.45	133925.0174	205001.6931	2022-Jan-08	0.00	14.40	11.40
130529.3812	6422.85	134283.9045	205430.0398	2022-Jan-09	0.00	14.40	11.70
130867.5076	6436.65	134628.1223	205844.7387	2022-Jan-10	0.00	14.40	6.75
131190.7984	6451.05	134956.9231	206247.9743	2022-Jan-11	0.00	5.70	8.70
131517.1305	6465.45	135288.7299	206651.0431	2022-Jan-12	0.00	0.00	14.40
131831.8011	6479.85	135608.5919	207054.6957	2022-Jan-13	0.00	0.00	9.45
132153.4276	6494.25	135935.5856	207466.6134	2022-Jan-14	0.00	0.00	14.40
132309.6428	6508.65	136094.407	207662.9408	2022-Jan-15	0.00	0.00	14.40
132627.5964	6523.05	136417.4563	208070.6662	2022-Jan-16	0.00	0.00	14.40
132950.6536	6537.45	136745.8744	208498.7284	2022-Jan-17	0.00	0.00	14.40
133293.2692	6548.85	137094.1685	208929.9087	2022-Jan-18	0.00	10.65	13.50

Note: site verification still required to confirm nameplate capacities, etc.

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Whole facility M&V

Option C case study: medical office natural gas savings

- Medical office in Southeast U.S.
- Natural gas savings due to two programs: behavior change program and recommissioning
- Option C (whole facility) selected as multiple systems are affected by the measures
- Monthly natural gas data from utility meter available

Space heating hot water piping

Photo by Eric Mazzi

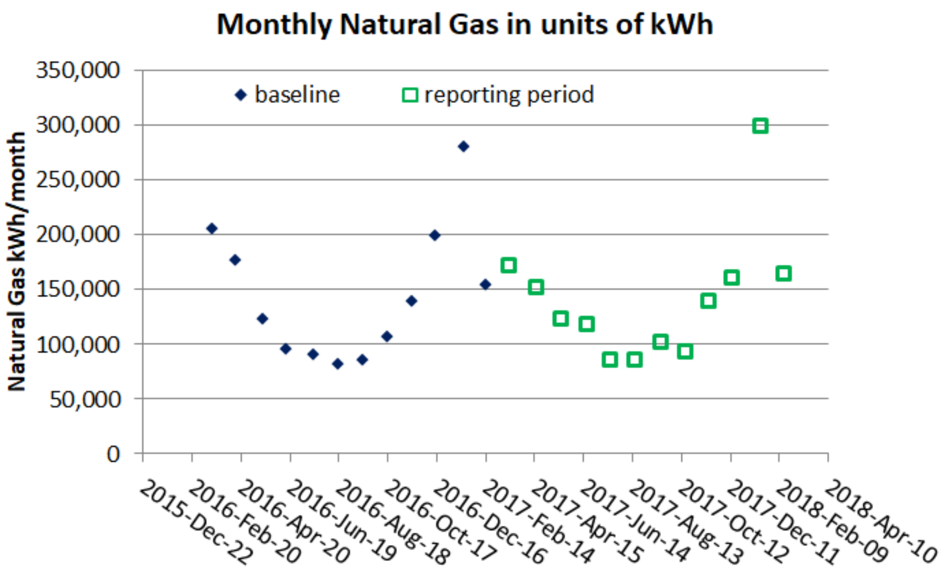
Option C case study: medical office natural gas savings

A baseline model is developed using monthly natural gas data:

*kWh/month = 94,292 + 257.0 * HDD/month*

Model statistics:

- Cv(RMSE) = 0.18 or 18%
- Bias error <0.005%
- R^2 = 0.84
- p-values & F-statistic < 0.01



Option C case study: medical office natural gas savings

M&V results:

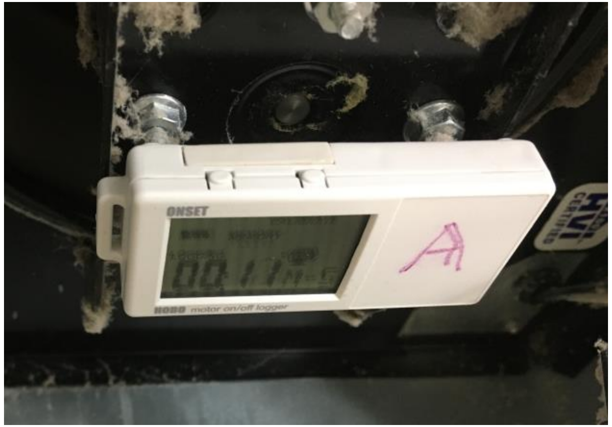
- Reporting period predicted consumption using baseline model: 1,836,000 kWh/yr (or 6,610 GJ/yr)
- Reporting period actual consumption: 1,689,000 kWh/yr (or 6,080 GJ/yr)
- M&V savings: **147,000 kWh/yr** (or 530 GJ/yr), 8% of baseline
- Routine adjustments: heating degree days (HDD)
- Non-routine adjustments: none identified

Low-cost metering tips

Runtime and other loggers

Lighting 'on' time

Lighting intensity (for dimming)



Motor operating time (magnetic 'stick on' or current switch)

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Electric submetering

- Three-phase power meters (requires ticketed electrician)
  - Time series logging built in
  - Bi-directional capability (e.g., solar PV; regenerative motors)

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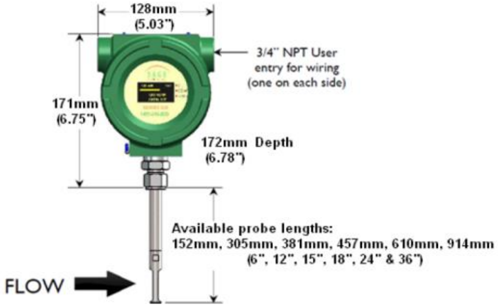
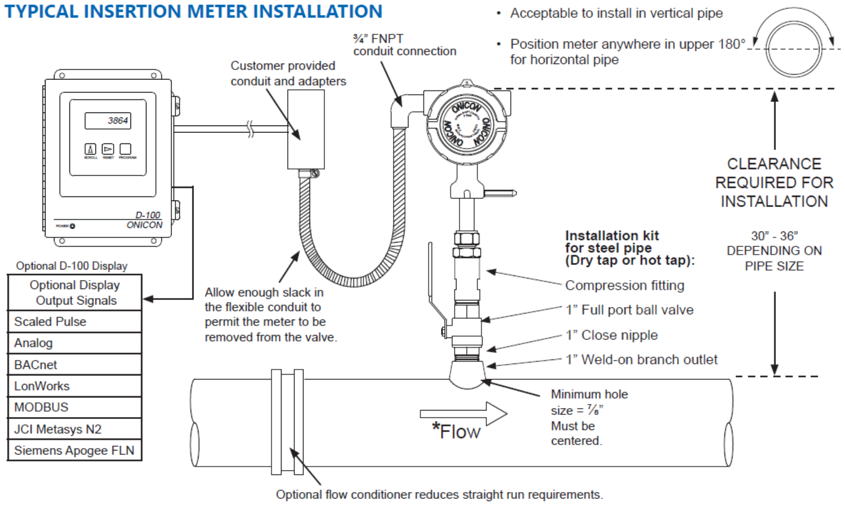
Natural gas sub-metering

- Thermal mass meters.
- Install so that meter can be removed without equipment shutdown, and meter reused for other equipment.





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Metering resource: DOE Metering Best Practices (2015)

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Metering Best Practices: A Guide to Achieving Utility Resource Efficiency, Release 3.0

SA Parker
WD Hunt
KM Fowler
WF Sandusky
GP Sullivan
BK Boyd
KL McMordie Stoughton
TM Koehler
R Pugh

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Metering resource: ASHRAE 14-2023, Appendix A

ASHRAE Guideline 14-2023
(Supersedes ASHRAE Guideline 14-2014)

Measurement of Energy, Demand, and Water Savings

Table A-9 Measurement Methods for Flowmeters

Measurement Device	Accuracy	Sensor Installation and Maintenance	Measurement Procedures	Comments
Portable ultrasonic flowmeter	5%	1 h for instrumentation technician; normal maintenance	Meter sensor is adjustable to fit a variety of pipe diameters.	Proper application and installation are critical. Potentially useful for in-field sensor verification.
In-line or insertion flowmeter	2%	4 h for instrumentation specialist; high maintenance	Flowmeter is inserted into pipe through weldolet. Signal cable is routed to a DAS.	Includes welding and hot-tap costs. Various flowmeter types are available. Routine recalibration is important.
Accumulating flowmeter	1% to 2%	1 h each for plumber and instrumentation technician; normal maintenance	Hot-water rated accumulating water meter installed on water line to be measured.	Requires licensed plumber for installation. Visual reading of accumulating register.
Pulse flowmeter	2%	1 h for plumber, 1 h for instrumentation technician; normal maintenance	A utility-grade pulse initiating water meter is installed in the water line to be measured. Signal wire is routed to the DAS.	A licensed plumber will typically be required for installation.

Table A-3 Measurement Methods for Electrical Use

Measurement Device	Accuracy	Sensor Installation and Maintenance	Measurement Procedures	Comments
Existing energy meter	1%	1/2 h for instrumentation technician; zero maintenance	Read existing utility energy meter.	Where possible, obtain metering documentation from the utility provider.
Existing demand meter	1%	Instrumentation technician, 1/2 h; zero maintenance	Read existing utility demand meter.	
Portable wattmeter	1% to 5%	1/2 h for instrumentation technician, mainly to set up for measurement; normal maintenance	Use clamp-on wattmeter.	Reference voltage typically obtained by installing spring clips on electrical panel lugs. Should one of the clips become disconnected and go to ground in the process of obtaining a measurement, a potentially hazardous and damaging electrical failure will result.

Table A-4 Natural Gas Flowmeter Comparison

Meter Type	Maximum Gas Pressure, psig	Maximum (Minimum) Capacity, scfh	Typical Accuracy/ Rangeability	Advantages	Disadvantages
Diaphragm	100	5000 (no minimum)	±1% 100:1	Inexpensive; good at measuring low flow rates	Mechanical components can become fouled and fail; temperature correction recommended.
Rotary	285	16,000 (1000 scfh min)	±1% 30:1 to 120:1	Good for commercial and industrial gas flow measurement	Mechanical components can become fouled and fail.
Turbine	300	150,000 (50,000 scfh minimum)	±1% of reading	Great for large gas flow rates, such as central heating plants; low pressure drop	Expensive—not good for measuring low flow rates
Thermal gas mass flow	300	384,000 (no minimum)	±1% +0.2% of full scale	Easy to install	Straight pipe is critical for accuracy and stability.

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Summary

Low-cost M&V summary

Project funding stakeholders should assess: what is purpose and value of M&V?

Consider operational verification only

Consider operational verification plus lower-cost M&V methods (retrofit isolation Option A, sampling, whole facility Option C, use of BAS/EMIS data)

Low-cost metering options are available (portable and temporary instruments, electricity sub-metering, natural gas sub-metering)

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Free M&V Resources

- Efficiency Valuation Organization (create a free account)
- IPMVP protocols:
    - IPMVP Core Concepts (2022)
    - (future) new version of the Uncertainty Assessment Guide
    - M&V for solar PV, demand response and more
- Bonneville Power Authority:
    - Application Guides (e.g. peak demand)
    - Reference Guides (e.g. regression modelling for M&V)
- ASHRAE 14-**2023** “Measurement of Energy, Demand, and Water Savings”

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Q&A: Ask us anything (related to M&V)!

Thank you!

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