NEW YORK STATE OF OPPORTUNITY. | Geothermal Clean Energy Challenge

Geothermal Clean Energy Challenge: Standardized Measurement & Verification Requirements for Ground Source Heat Pumps

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Prepared for:

New York Power Authority (NYPA)

and

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1. Definitions[1]

Baseline Adjustments The adjustments to energy savings to account for changes in operational and performance characteristics within the measurement boundary that occur during the reporting period and are unrelated to the energy conservation measure (ECM).

Baseline Period The period before implementation of an energy conservation measure at a facility or on a system. This may be the time required for an instantaneous measurement of a constant quantity, or one full operating cycle of a system or facility.

Calibrate The process of checking simulated energy consumption and demand against measured energy and demand. Once the mean difference between simulated and measured quantities is within acceptable tolerance, the simulation is called "calibrated".

Cycle The period between the start of successive similar operating modes of a facility or piece of equipment whose energy use varies in response to operating procedures or independent variables.

Independent Variables The routinely changing factors affecting energy consumption and demand within the measurement boundary. These variables are used for developing regression models and making routine adjustments.

Interactive Effects Energy effects created by an energy conservation measure that are outside the measurement boundary.

Measurement Boundary A theoretical boundary drawn around equipment or systems that defines the metering location and the operational and performance characteristics that affect energy savings.

Non-Routine Adjustments Individually engineered calculations to account for changes in static factors within the measurement boundary during the reporting period.

Regression Analysis A form of statistical analysis used to find the mathematical relationship between measured energy consumption or demand and independent variables.

Routine Adjustments Calculations that account for changes in independent variables within the measurement boundary during the reporting period.

Static Factors Operational and performance characteristics within the measurement boundary that affect energy consumption and demand, but are not used as the basis for routine adjustments.

[1] Adapted from the Efficiency Valuation Organization (EVO) International Performance Measurement and Verification Protocol (IPMVP) Framework: https://evo-world.org/en/products-services-mainmenu-en/protocols/ipmvp.

2. Introduction

The New York Power Authority (NYPA) and the New York State Energy Research and Development Authority (NYSERDA) launched the Geothermal Clean Energy Challenge in December 2017 to stimulate and finance the installation of best-in-class, large-scale geothermal systems. As part of the Challenge, NYPA and NYSERDA developed information resources to facilitate installation of geothermal, also known as ground source heat pump (GSHP) systems, and this Standardized Measurement & Verification Requirements document is one of the resources developed.

This document is intended to help engineers, architects, and other stakeholders understand program requirements for Measurement and Verification (M&V) of GSHP systems. It is organized as follows:

- Summary of special considerations for GSHP systems (Section 3),
- Primer on M&V (Section 4)
- Step-by-step approach for implementing M&V requirements (Section 5)

Because the Geothermal Clean Energy Challenge supports GSHP installations with a heating or cooling capacity of 100 tons or more, this document is focused on GSHP installations at that scale. While the information is oriented towards relatively large systems, this document may also be relevant for smaller GSHP installations.

3. M&V Considerations for Ground Source Heat Pump Systems

This document provides guidance on M&V activities required for GSHP systems in the Geothermal Clean Energy Challenge. It is applicable to a wide variety of new construction and retrofit project types including:

- Property Owners – Commercial and Institutional Organizations (e.g., government agencies, colleges and K-12 schools, hospitals)[2]
- GSHP System Types – Open and closed loop systems; hybrid systems
- End-Use Applications – Space heating and cooling; domestic hot-water; refrigeration; pool and spa water heating; and road way conditioning

The M&V of GSHP systems is fundamentally similar to the M&V of conventional heating, ventilation, and air conditioning (HVAC) equipment. However, there are unique characteristics of GSHPs that need to be considered during the M&V process. Three of these characteristics are described below and influence which International Performance

[2] Though this document is intended as a helpful guide, readers should be aware that special M&V requirements may be included in the contracts of government agencies or other possible GSHP system hosts.

Measurement & Verification Protocol (IPMVP) Option(s) are suitable for calculating energy savings from a GSHP system.

Retrofit Projects

In GSHP retrofit projects, a wholesale replacement of the facility's existing HVAC system may be required. This provides an opportunity to simultaneously increase the efficiency of other building systems and equipment. By reducing system load requirements, the GSHP system can be designed with fewer loops and wells, thus reducing GSHP capital investment costs while helping to offset cost of the additional building improvements.

However, this bundling of efficiency measures can make the M&V and quantification of savings from the GSHP retrofit more difficult. The interactive effects of other energy measures requires a larger measurement boundary, additional metering, or building simulation to isolate the GSHP performance.

System Performance

Conventional HVAC systems in commercial and institutional buildings are controlled to maintain internal space temperature (or humidity) based on variable internal loads and ambient temperatures. GSHPs are fundamentally similar in that their performance and load are variable. However, because the heat source and heat sink are isolated from extreme changes in ambient temperature, the GSHP performance is less variable when compared to the conventional air- and water-cooled equipment. A challenge unique to GSHP systems is predicting and verifying their heating and cooling operational performance and efficiencies, which is driven by fluid temperature and depends on site ground bore field and loop conditions and building space heating and cooling load requirements.[3]

Energy Types

Conventional HVAC systems may consume electricity, or a combination of electricity and fossil fuels such as natural gas, heating or fuel oil, or propane to maintain minimum condenser water loop temperature. In contrast, GSHPs consume only electricity. Projects where fossil fuel systems are replaced with the GSHPs may find one specific IPVMP option (Option D) as the most appropriate M&V method.

4. Measurement & Verification Primer

M&V is an approach to reliably estimate energy savings from implementation of energy efficiency or conservation projects that improve energy performance or usage. M&V is based on a combination of measured and stipulated parameters and calculations.[4] *Measurement*

[3] Information drawn from US Department of Energy (DOE) Federal Energy Management Program (FEMP) M&V Documents: http://ateam.lbl.gov/mv/.

[4] Goldberg et al. 2015. "The Changing EM&V Paradigm: A Review of Key Trends and New Industry Developments, and Their Implications on Current and Future EM&V Practices." NEEP Regional Evaluation, Measurement & Verification Forum.

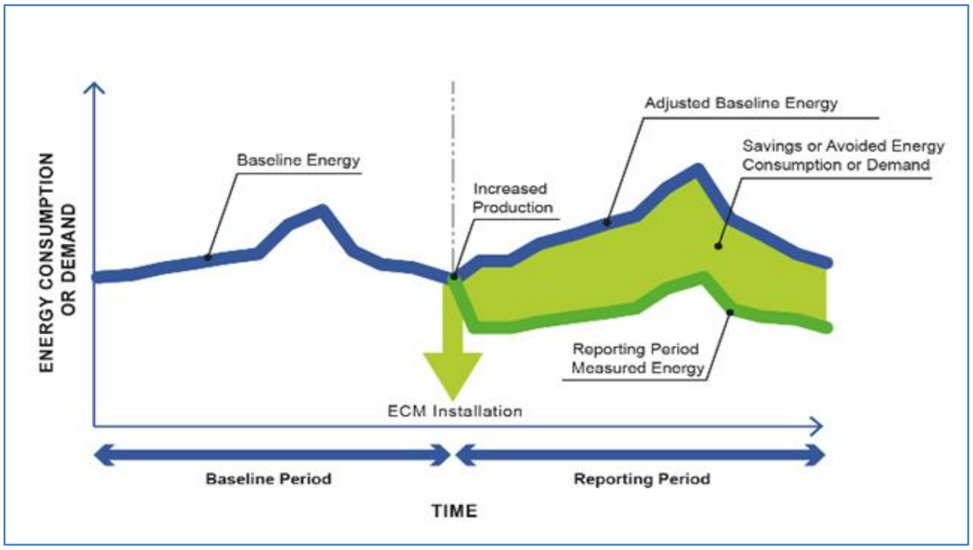
involves measuring the baseline and reporting period energy use. *Verification* involves (i) verifying that the energy efficiency measures have been installed and are operating properly, and (ii) accounting for changes in facility operational and performance conditions within the measurement boundary. From **Equation 1** below, energy savings are calculated as the difference between the baseline and reporting period energy consumption, plus or minus any adjustments.[5] **Exhibit 1** is an illustration of the M&V equation.

Equation 1 – IPMVP Energy Savings Equation

$$\textbf{Energy Savings} = (\textbf{\textit{Baseline Energy}} - \textbf{\textit{Reporting Period Energy}}) +/- \textbf{\textit{Adjustments}}$$

Adjustments remove the energy consumption that occurs from changes to operational or performance conditions that are unrelated to implementation of the energy measure that occur during the reporting period. These adjustments allows for the baseline and reporting period energy savings to be compared under similar conditions.

Exhibit 1 - Illustration of M&V Savings Equation



Source: EVO IPMVP

Adjustments may be either routine or non-routine. *Routine adjustments* are changes in parameters that can be expected to occur throughout post-retrofit period and for which a relationship with energy use can be identified.[6] Seasonal or cyclical variations from weather or building occupancy in educational facilities are examples of when routine adjustments are applied. *Non-routine adjustments* are changes in parameters that cannot be predicted and for

[5] Efficiency Valuation Organization. 2012. "International Performance Measurement and Verification Protocol: Concepts and Options for Determining Energy and Water Savings, Volume I. EVO 10000-1:2012." Retrieved from https://library.cee1.org/sites/default/files/library/10845/IPMVP_Vol_1_2011_EN-20.1.2012-1.pdf.

[6] Ibid.

which a significant impact on energy use is expected.[7] Increasing the quantity of computers in a computer lab or increasing the density of beds per room in a hospital are examples of when non-routine adjustments are required.

4.1 Reasons for Conducting Measurement & Verification

Investment in energy projects is partially dependent on M&V to quantify the impact of energy and energy cost savings. M&V demonstrates the value of energy efficiency by quantifying real, reliably-calculated savings and providing feedback and validation on implemented energy efficiency measures, which is important for public support and funding for energy efficiency programs.[8]

M&V can be used to accurately assess project energy savings, allocate risk between the contractor and the customer, reduce uncertainties to reasonable levels, monitor equipment performance, identify additional savings opportunities, and improve O&M practices.[9]

The Geothermal Clean Energy Challenge uses M&V to quantify estimated energy savings using a transparent process that will ensure robust information is developed on the technical and economic viability of GSHP systems in New York State facilities.

4.2 Program Standard for Conducting Measurement & Verification

IPMVP has become the internationally accepted standard for quantifying energy and energy cost savings from energy and water efficiency, demand management, and renewable energy projects. It has been adopted as NYSERDA's measurement and verification standard and is the basis of M&V for the Geothermal Clean Energy Challenge.

IPVMP provides a robust yet flexible framework for measuring, computing, and reporting energy savings. It defines key terms and describes methods that must be considered during the M&V process and for data sampling and accounting for uncertainty associated with measurements and models. Adherent projects follow the six guiding principles of being: accurate, complete, conservative, consistent, relevant, and transparent.[10] M&V practitioners are able to create M&V Plans that address the unique conditions of their projects by following one of four options for measuring and verifying savings.

4.3 Four Options for Measuring and Verifying Energy Savings

IPMVP provides flexibility for selecting the option that appropriately balances the costs of conducting M&V with the accuracy of reported savings. These options are summarized in

[7] Ibid.

[8] Evaluation, Measurement and Verification (EM&V). (n.d.). Retrieved February 2018, from American Council for an Energy-Efficiency Economy (ACEEE): http://aceee.org/topics/evaluation-measurement-and-verification-emv.

[9] Information drawn from US Department of Energy (DOE) Federal Energy Management Program (FEMP) M&V Documents: http://ateam.lbl.gov/mv/.

[10] Efficiency Valuation Organization, 2012

Exhibit 2 and can be divided into two groups represented by the measurement boundary: retrofit isolation and whole building.

Retrofit Isolation Options A and B isolate the energy conservation measure by placing the measurement boundary around only the affected equipment or systems. This narrows the measurement boundary, which reduces verification requirements and increases certainty in reporting savings. However, this narrowing can involve additional metering requirements and difficulty in accounting for interactive effects.

Alternatively, *Whole Building* Options C and D place the measurement boundary around the entire facility, which can reduce metering requirements when facility-level meters are present, but can reduce certainty in savings estimates.

Exhibit 2 - IPMVP Adherent Approaches[11]

IPMVP M&V Approach	Description	Pros and Cons	Geothermal Clean Energy Challenge Applicability
Option A: Retrofit Isolation: Key Parameter(s)	Short- or long-term measurement of key performance parameters impacting energy use of the ECM-affected system (stipulations allowed)	Pros: • Accurate when system load or performance may be stipulated • Less expensive than Option B Cons: • Larger uncertainty than Option B • Additional performance verification required when compared to Option B.	Depends on individual project circumstances
Option B: Retrofit Isolation: All-Parameters	Short- or long-term measurement of all parameters impacting energy use of the ECM-affected system (stipulations not allowed)	Pros: • More accurate and precise than Option A • May be used with multiple ECMs Cons: • More costly than Option A • Requires installation of sub-meters	Yes
Option C: Whole Facility Building	Whole-building utility billing analysis (regression analysis)	Pros: • May be used when multiple ECMs are implemented • No uncertainty with revenue-grade meters Cons: • Not able to isolate the individual impacts of bundled energy measures • Difficult to validate energy savings <10%	Yes

[11] Franconi, E. et al. 2017. "The Status and Promise of Advanced M&V: An Overview of "M&V 2.0" Methods, Tools, and Applications." Berkeley, California: Lawrence Berkeley National Laboratory. Retrieved from https://eta.lbl.gov/sites/all/files/publications/lbnl-1007125.pdf.

IPMVP M&V Approach	Description	Pros and Cons	Geothermal Clean Energy Challenge Applicability
Option D: Calibrated Simulation Building	Calibrated building simulation modelling	Pros: • May be used when a reliable baseline does not exist (New Construction or no meter is available) • Can be used to isolate the performance of individual energy measures Cons: • Calibration required on a monthly basis • Requires extensive metering and input of measured data	Yes

5. Program M&V Requirements

This section provides guidance for conducting M&V in the Geothermal Clean Energy Challenge by adapting the flexible requirements of IPMVP. Projects participating in the Challenge shall follow the following six-step process, which supports development and documentation of the M&V Plan and M&V Report as key elements of a successful GSHP project.

- Step 1 – Comply with General Program Requirements
- Step 2 - Determine the Measurement Boundary
- Step 3 - Select an M&V Option
- Step 4 – Follow M&V Option Guidance
- Step 5 – Submit M&V Plan for Approval before Project Commencement
- Step 6 – Submit Final M&V Report for Approval at Project Completion

5.1 Step 1 – Comply with General Program Requirements

M&V shall be performed in adherence with IPMVP's protocols for determining energy savings. The M&V contractor shall following the requirements of *Chapter 7 – Adherence with IPMVP in the IPMVP Concepts and Options for Determining Energy and Water Savings, Volume 1.*

M&V shall be performed by a third party not responsible for the design or commissioning of the GSHP project. The M&V contractor shall have relevant and demonstrated experience performing M&V for GSHP projects of similar size and complexity and preferably be a licensed professional engineer, Certified Energy Manager (CEM), Certified Measurement and Verification Professional (CMVP), or hold a similar relevant certifications or credentials.

5.2 Step 2 - Determine the Measurement Boundary

The measurement boundary defines the scope of activities performed during M&V. It is defined as either *isolation retrofit* or *whole-building*. It delineates where metering is located to isolate equipment, systems, or the whole building, and the extent of performance verification required to document operational and performance characteristics, such as independent variable and static factors. It is determined by the size and variability of the measure, the cost and feasibility of sub-metering, the availability and requirements for data collection, and the interactive effects with other facility measures.

Retrofit Isolation

In general, the smaller measurement boundary of retrofit isolation provides greater accuracy in reported savings and reduces the cost of performance verification. In cases where existing building and GSHP systems may be isolated, it is preferable to use the narrower isolation retrofit boundary around the affected systems. Place the measurement boundary at the system or equipment-level when:

- Sub-metering is in place and may be used to isolate existing systems during the baseline period consumption
- Interactive effects with other systems and equipment are either immaterial or can be readily quantified.

Whole-Building

In practice, the larger whole-building measurement boundary may more practical and cost-effective for GSHP retrofit projects that undergo a wholesale replacement of building terminal and heat rejection systems and equipment. In those cases, it can be difficult and costly to meter existing systems planned for retrofit and is therefore often preferable to place the measurement boundary around the facility. Place the measurement boundary around the facility when

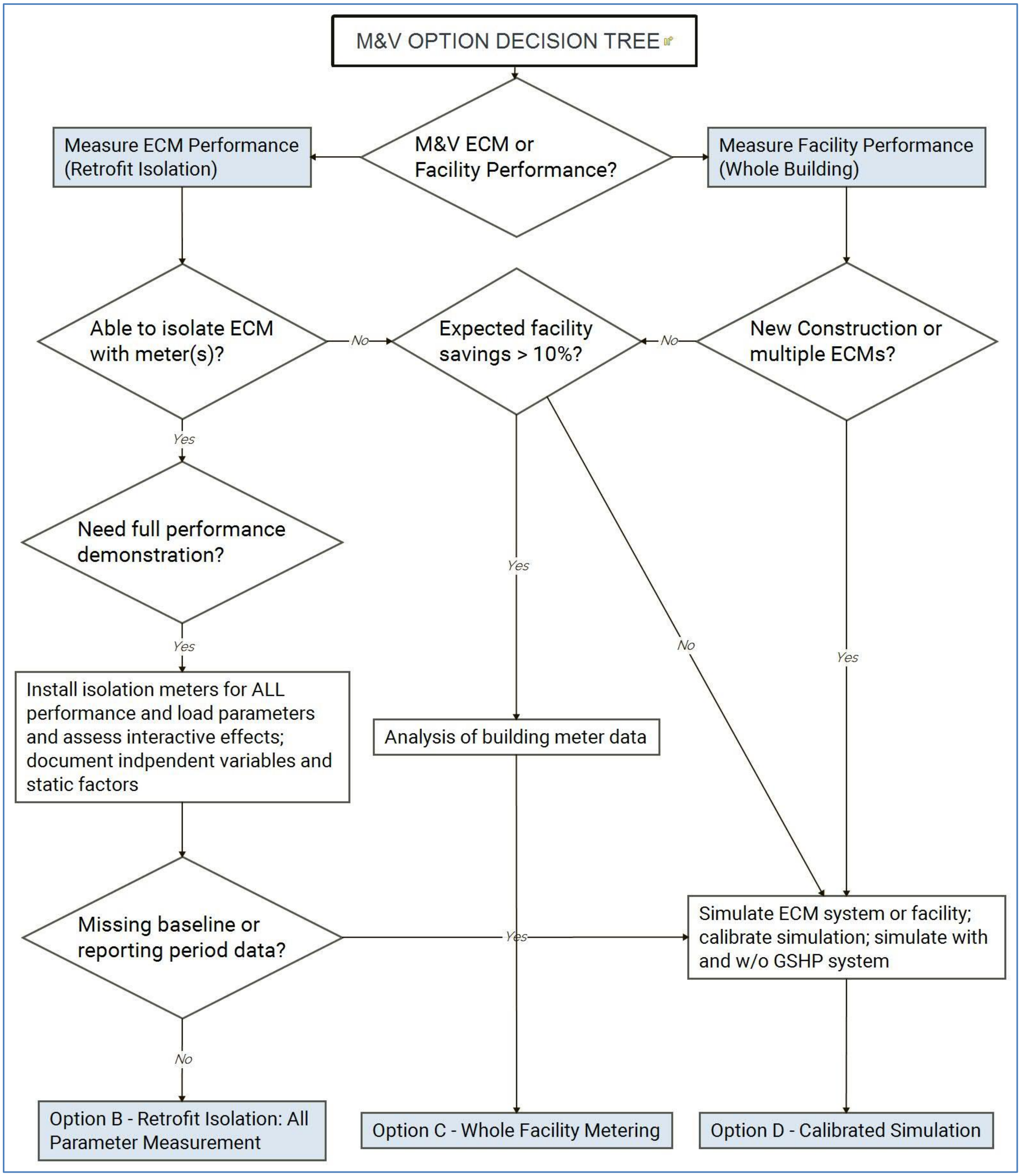
- The retrofit project cannot be readily isolated with metering
- There are significant interactive effects with other building systems, or the project consists of multiple energy conservation measures

5.3 Step 3 - Select an M&V Option

Project conditions can strongly influence the location of the measurement boundary, which therefore influences the M&V Option. Several common criteria are listed below and can be used to guide and expand upon the decision making process outlined in **Exhibit 3**.

Alongside these criteria, the cost of administering M&V should be weighed. Such administrative costs typically range from 3-5% of annual energy savings, depending upon the measure complexity and availability of energy and operational and performance data. Generally, the most appropriate IPMVP is the one that provides the best balance between M&V administrative costs (as a percentage of energy savings) and measurement accuracy.

Exhibit 3 - M&V Decision Tree for GSHP Projects[12]



Common M&V Criteria

- **M&V ECM or Facility Performance:** When the GSHP system is the only ECM being implemented at the facility, the GSHP system should be isolated for M&V and the calculation of energy savings (Option B). If other building systems are concurrently being retrofitted (e.g., building envelope improvements to reduce heating and cooling loads) or the performance and load of the GSHP performance cannot be isolated, the measurement boundary should be placed at the whole building level (Option C or D). Option A may be adequate when operational performance are known and can be stipulated, for example, spa or pool heating, refrigeration, and domestic hot water. However, when GSHPs are installed that cover these and HVAC end-uses, Option A may not provide sufficient certainty.
- **Able to Isolate GSHP System Performance**: Retrofit isolation Option B can be used when system- or equipment-level metering is available (or can be readily installed) to monitor energy consumption during the baseline and retrofit periods. For these options, facility performance and operational characteristic data must be collected for independent variable or static factor calculations, and any interactive effects must be quantifiable.
- **Need Full Performance Demonstration**: Similar to conventional HVAC systems, the energy consumption of GSHP systems is dependent upon facility indoor operating conditions and ambient weather conditions. Because these parameters are variable, when an isolation retrofit option is used, it is preferable to measure all performance and load parameters (Option B), rather than use stipulated values (Option A).
- **Missing baseline or reporting period data**: In addition to energy performance and usage data, facility performance and operational characteristic data must be collected for use as independent variables or static factors for energy calculation adjustments. If, for example, independent variables used in regression models (Option B or Option C) cannot be collected at the same interval as meter data, it may not be possible to isolate the system, requiring the use of calibrated simulation (Option D) to verify savings.
- **Expected Facility Savings >10%**: Savings less than 10% of annual energy consumption can be difficult to validate when regression model uncertainty is high and the absolute amount of energy savings are small. When whole building expected savings from GSHP systems are greater than 10%, Option C may be used, otherwise M&V should be performed using Option D.
- **New Construction or No Baseline**: For New Construction projects or projects where the baseline condition is no longer available, Option D is generally the only available

[12] Adapted from Efficiency Valuation Organization. Note: IPMVP Option A has been intentionally omitted from this guidance document because the operation and performance of GSHP systems and the traditional HVAC systems from which their savings are compared, are variable and requires a full performance demonstration.

method for performing M&V in compliance with IPMPV. Option D is also a preferred method for reporting savings on a single ECM (e.g., GSHP system) within a multi-ECM retrofit.

5.4 Step 4 - Follow M&V Option Guidance[13]

Option B – Retrofit Isolation: All Parameter Measurement

Baseline M&V Activities:

- Determine what operational and performance characteristics (i.e., independent variables) are within the measurement boundary and affect energy use.
- Establish a baseline period that covers the range of expected system operating conditions, for at least one operational performance cycle. For most GSHP projects, the baseline period will be the 12-month period immediately prior to installation of the GSHP system.
- Develop a metering plan that places meters at the measurement boundary. Install key parameter meters (e.g., spot-meters, short-term meters, or long-term trending meters) as required to minimize interactive effects. Confirm calibration and accuracy of existing and new meters.
- Develop protocols for collecting operational and performance data including data for independent variables and static factors within the measurement boundary.
- Develop and submit M&V Plan (Section 5.5)

Reporting Period M&V Activities:

- Verify GHSP system has been properly installed. Review all operational and performance characteristics (i.e., independent variables and static factors) to ensure that the baseline is still appropriate. Recalculate the baseline if required.
- Confirm meter accuracy and calibration.
- Conduct one or more performance test to demonstrate operational and performance characteristics through one full cycle. Measure the same parameters as measured during the baseline period using the same meters.
- Calculate energy consumption and cost savings using measured values applied to baseline load profile.
    - Adjust the baseline energy consumption to account for interactive effects from other measures.
    - Develop regression or other engineering-based models to establish a statistical relationship between baseline energy consumption and independent variables. Assess model for certainty and bias.
    - Use the baseline model to adjust the baseline energy consumption to be predictive under conditions of the reporting period.
    - Subtract reporting period measured energy consumption from adjusted baseline energy consumption.

[13] This section is adapted from Information drawn from US Department of Energy (DOE) Federal Energy Management Program (FEMP). Note: IPMVP Option A has been intentionally omitted from this guidance document because the operation and performance of GSHP systems and the traditional HVAC systems from which their savings are compared, are variable and requires a full performance demonstration.

  - Apply stipulated energy rates to determine cost savings.
- Develop and submit M&V Report (Section 5.6).

Option C – Whole Building

Baseline M&V Activities:

- Determine what operational and performance characteristics (i.e., independent variables) are within the measurement boundary and affect energy consumption.
- Establish a baseline period that covers the range of expected system operating conditions, for at least one operational performance cycle. For most GSHP projects, the baseline period will be the 12-month period immediately prior to installation of the GSHP system.
- Obtain data from utility meters or New York Energy Manager (NYEM), if available, at the facility-level. Alternatively, install facility-level meters to capture long-term performance trends. Confirm calibration and the accuracy of non-revenue grade meters.
- Develop protocols for obtaining or collecting whole facility operational and performance data for independent variables and static factors.
- Develop and submit M&V Plan (Section 5.5)

Reporting Period M&V Activities:

- Verify GHSP system has been property installed. Review all operational and performance characteristics (i.e., independent variables and static factors) to ensure that baseline is still appropriate. Recalculate baseline if required.
- Confirm meter accuracy and calibration for non-revenue grade meters.
- Measure operational and performance data through one full cycle. Measure the same parameters as measured during the baseline period using the same meters.
- Calculate energy consumption and cost savings using measured values applied to baseline load profile.
  - Adjust the baseline energy consumption to account for interactive effects from other measures.
  - Develop regression or other engineering-based models to establish a statistical relationship between baseline energy consumption and independent variables. Assess model for certainty and bias.
  - Use the baseline model to adjust the baseline energy consumption to be predictive under conditions of the reporting period.
  - Subtract reporting period measured energy consumption from adjusted baseline energy consumption.
  - Apply stipulated energy rates to determine cost savings.
- Develop and submit M&V Report (Section 5.6).

Option D – Calibrated Simulation

Baseline M&V Activities:

- Develop a building energy model computer simulation of the building. If a model was developed during the design phase for code compliance, adjust the model to represent actual measured operating performance conditions.
- Establish a baseline period that covers the range of expected system operating conditions, for at least one operational performance cycle. For most GSHP projects, the baseline period will be the 12-month period immediately prior to installation of the GSHP system.
- Develop a metering plan that uses a combination of whole-building meters (e.g., utility meters or data from NYEM) and sub-meters to measure the performance of the GSHP system. Install sub-meters (e.g., spot-meters, short-term meters, or long-term trending meters) as required to minimize interactive effects. Confirm calibration and accuracy of existing and new meters.
- Develop protocols for collecting whole facility and GSHP borefield and system operational and performance data for energy usage, independent variables, and static factors.
- Develop and submit M&V Plan (Section 5.5)

Reporting Period M&V Activities:

- Verify GHSP system has been property installed.
- Collect 12-months of energy usage and operational and performance characteristics (i.e., independent variables and static factors) data for the GSHP equipment and borefield. For the borefield, collect data for the following parameters[14]
    - Soil formation thermal conductivity and deep earth temperature (in situ test measurements).
    - Borehole depth, pipe dimensions, and thermal properties of grouting material.
- Confirm meter accuracy and calibration for non-revenue grade meters.
- Simulate building energy model with post-retrofit conditions and retrofitted equipment. Verify that model simulates actual indoor and GSHP borefield conditions properly.
- Calibrate building energy model (BEM)
    - Compare monthly BEM consumption data to measured energy consumption during the reporting period, for all energy types, and check for normalized mean bias error.
    - Revise the BEM using operational and performance characteristics as inputs to reduce monthly differences to an acceptable level.
- Apply stipulated energy rates to determine cost savings.
- Develop and submit M&V Report (Section 5.6).

[14] Information drawn from US Department of Energy (DOE) Federal Energy Management Program (FEMP) M&V Documents: http://ateam.lbl.gov/mv/.

5.5 Step 5 - Submit M&V Plan before Project Commencement

The M&V contractor shall develop an M&V Plan that includes all information required in *Chapter 5 - M&V Plan Contents* in the *IPMVP Concepts and Options for Determining Energy and Water Savings, Volume 1*. It should detail the energy conservation measure, the measurement boundary, the baseline and reporting period energy consumption and operational and performance conditions, all related assumptions, and how the calculation of energy and energy cost savings will be performed.

The M&V Plan shall be approved by the building's representative and submitted to NYPA for approval before proceeding with work. The M&V contractor is expected to execute M&V according to the approved plan and notify NYPA of any material changes.

5.6 Step 6 - Submit M&V Final Report at Project Completion

The M&V contractor shall develop an M&V Report as described in the M&V Plan. It shall include all information required in *Chapter 6 - M&V Reporting* in the *IPMVP Concepts and Options for Determining Energy and Water Savings, Volume 1*, including but not limited to observations of energy data, baseline adjustments, and calculated energy and energy cost savings. The report shall be submitted to NYPA upon project completion.

6. Additional M&V Resources

The resources below complement this guidance document and provide additional background on M&V, and links to industry standard tools, documents, and other resources available for implementing M&V in energy projects.

Resource	Description of Available Resources	Website
California Commission Collaborative, Energy Charting and Metrics Tool	A Microsoft Excel based tool that enables the examination of building energy use patterns and developing regression models used for M&V.	https://www.cacx.org/PIER/ecam/
Efficiency Valuation Organization (EVO), International Performance Measurement and Verification Protocol (IPMVP)	Website that provides access to the IPMVP standards for measuring and reporting energy, demand, and cost savings. The webpage summarizes the purpose, scope, benefits, and uses of M&V in energy projects.	https://evo-world.org/en/products-services-mainmenu-en/protocols/ipmvp
Lawrence Berkeley National Laboratory, Measurement & Verification Portal	Website provides resources and tools that support conducting M&V activities. The site includes example documents, interactive tools (IPMVP Option Selector), discussion boards, and trainings.	http://mnv.lbl.gov/home
National Institute of Building Sciences, Whole Building Design Guide	Website provides an overview of GSHP systems and specific details for considering GSHP as part of a new construction and renovation projects.	https://www.wbdg.org/resources/geothermal-heat-pumps
U.S. Department of Energy, Federal Energy Management Program, Measurement and Verification Documents	List of resources to help organizations implement an M&V program, including implementation guidelines, checklists, risk matrices, etc.	http://ateam.lbl.gov/mv/
U.S. Department of Energy, Federal Energy Management Program, Measurement and Verification Activities Required in the Energy Savings Performance Contract Process	Website summarizes the four major M&V activities used for energy savings performance contract (ESPC) in government projects.	https://energy.gov/eere/femp/measurement-and-verification-activities-required-energy-savings-performance-contract