oTherm Best Practices for Data Providers – Part 1 Multiple Renewable Thermal Technologies

Version 1.0

oTherm Project Task 2:
Best Practices

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Introduction

The collection and analysis of data from building systems using renewable heating and cooling (RH&C) technologies has been recognized as high priority in addressing a number of market barriers. In a recent report[1] undertaken on behalf of NYSERDA, the importance of standardized data collection and the challenge to do so are highlighted:

> *"RH&C technologies are typically integrated within whole building HVAC systems, and are more difficult to isolate and measure performance than other technologies such as solar PV. Thus, it is essential that standardized data collection and performance protocols are developed to strengthen lender and financial player confidence in RH&C project performance and returns." NYSERDA Market Report*

One of the key interventions identified in the NYSERDA Market Report is to "gather on-site performance data to create a streamlined yet trusted measurement and verification (M&V) approach that can be applied to systems of all sizes".

The oTherm framework envisions meeting that need by leveraging readily available operating data from individual pieces of RH&C equipment to address a variety of needs related to the M&V of RH&C technologies. As part of this framework, a set of Best Practices documents provide guidance for both data providers and end users.

Best Practices typically have two characteristics – first they are based on evidence that they lead to an optimal outcome and second, they are amenable to widespread adoption. Here the focus is specifically on developing best practices for collecting data that can be used to efficiently assess performance of RH&C equipment installations. The optimal outcome is to provide data for streamlined and efficient M&V of a large number of installations. To attain widespread adoption, affordability and flexibility are favored over accuracy and rigid standardization.

The Best Practices for data providers are split into two parts. The first part (this document) focuses on the compatibility of a monitoring system with the oTherm framework. The second part focuses on documenting the characteristics of the building and the RH&C system that are necessary to interpret operating data from a monitoring system. The third Best Practices document is a guide to the implementation of the oTherm framework as part of a M&V program.

[1] Energy & Resource Solutions and Dunsky Energy Consulting. (2019). Renewable Heating and Cooling Financial Solutions Market Research - Final Report. NYSERDA.

The current oTherm project focuses on ground source heat pump (GSHP) technology as a specific use case; however, the overall goal is to develop a general framework that can be readily applied to other RH&C technologies.

This document summarizes the best practices when developing a RH&C performance monitoring program, considering both ground-source and air-source heat pumps (GSHP and ASHP, respectively). The best practices can be extended to other renewable thermal technologies, such as biomass furnaces and boilers and solar hot water system. As a result, many of the recommendations are general in nature. The set of best practices presented here *focus on best practices when considering the characteristics of a monitoring program relative to the oTherm framework. These may be existing technologies or ones being considered for development.*

The recommendations herein were developed though deliberations among the Renewable Thermal Alliance through in person workshops and online discussions. The recommendations are also informed by recent efforts in several New England states that have added thermal energy to their renewable portfolio standards and have implemented methodologies for measuring thermal energy production.

oTherm does not intend to be a standard for collecting data, rather a framework to aggregate, curate, and disseminate data in a standardized manner. Measurements can be obtained through a variety of means and it is up to the monitoring system manufacturer to adopt and deploy methods that are cost effective for their monitoring objective.

In some cases, the monitoring objective may be to provide meter-quality measurements that meet a metering standard and can be used for billing purposes, typically requiring very accurate temperature measurements. Other cases may focus on an objective of detecting ground loops that operate outside of design specification, allowing for a relatively coarse measurements of temperature. The oTherm framework enables data collected for a variety of monitoring objectives to be aggregated, so that those data can be available to assess other performance measures and facilitate the development of new performance metrics.

Compatibility of monitoring systems with oTherm extends along multiple dimension. This document summarizes the elements that a monitoring service provider (MSP) should consider in assessing the compatibility of their system with the oTherm framework (shaded portion of Figure 1). This also provides potential oTherm users a roadmap of the characteristics of a monitoring system when establishing an M&V program. Focusing on Best Practices rather than standards enables both the MSP and the M&V program manager to have discretion in weighing the recommendations relative to a specific objective. Best Practices for Data

Providers, Part 2, will focus on the HVAC contractor and M&V program manager. Best Practices for Data User focuses on using an oTherm instance for data analysis and reporting.

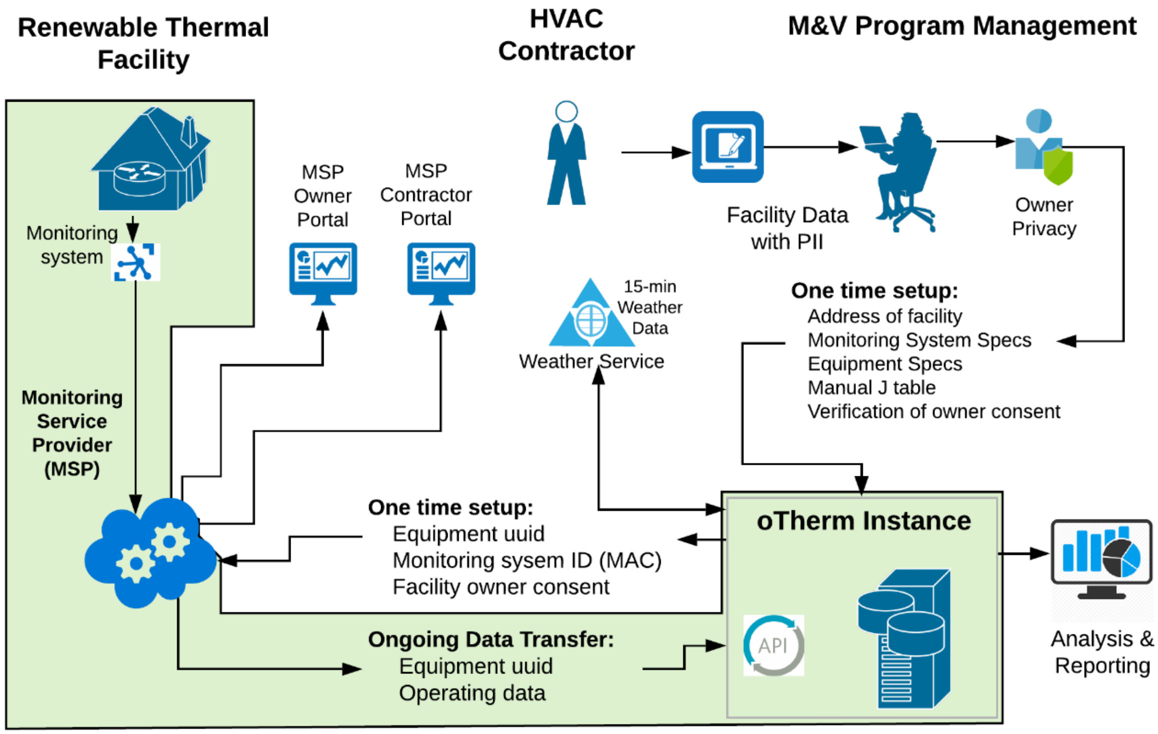

Figure 1. Illustration of oTherm data flow. This Best Practices document focuses on the collection of data through a set of monitoring service providers using web-based monitoring systems.

Monitoring Systems

In the oTherm framework, a 'monitoring system' is defined as a system that collects a specific set of measurements associated with an individual piece of RH&C equipment installed at a facility (building). A monitoring system is also unique in the methods by which data is collected, stored, and made available to end users. Monitoring systems will often be designed to meet multiple objectives serving a variety of end users. For example, a monitoring system may provide one set of data views to a building owner and a different data portal to the contractor servicing the equipment. oTherm does not interact with or modify these established and ongoing services. Instead, oTherm provides a mechanism for the monitoring service provider to share some select and anonymous operating data with an M&V program manager. This section provides an overview of considerations when developing a monitoring system and/or evaluating the suitability of an existing monitoring system for the oTherm Framework.

Data Management

So that data from oTherm can assist in quantifying the performance of RH&C technologies, it is imperative that monitoring systems are well defined and that the data they report are consistent, documented, and available for use.

Data elements

Data elements should be determined to meet monitoring system objective. For renewable thermal technologies, these will typically include measures of energy inputs and energy outputs and involve measurements of both electricity consumption and heat transfer.

The data elements may differ depending on RH&C technology of interest. For GSHP systems, the oTherm device-level data dictionary consists of 16 possible types of measurements, though an individual monitoring system will typically measure a small subset. General considerations for these types of measurements are discussed in the section 'Energy Measures'. All measures must be converted to proper units and offsets applied by the monitoring system provider. Only the resulting measure is provided to oTherm.

Data schemas

One of the challenges in standardizing data models for renewable thermal systems is the wide range of measurement types that are necessary and the various technologies that can be used to obtain measurements. For the data model to be useful, it must be sufficiently flexible to accommodate a varied and continually evolving set of measurement technologies but also enable ease of use once the characteristics of a monitoring system are specified. The oTherm framework has specific data schemas for both static site information and ongoing operating data that are defined in the facility-level and device-level data dictionary documents, respectively.

To facilitate sharing of data from the MSP to oTherm, it is highly recommended that the MSP define a relational database schema for static data and either a SQL or no-SQL schema for operating data. The oTherm framework specifies the format[2] by which data is received and the MSP must provide the data consistently in that format.

The specific data elements and the organization of Device-level Data Model has been developed for GSHP systems (Davis and Carlin, 2019) which can be readily modified for other renewable thermal technologies.

Data policies

Monitoring service providers interested in providing data to oTherm should establish data policies that protect the privacy of the end user while also making data available to third parties. For example, it is common for MPSs to share data with equipment contractors to assist with maintenance and service calls. Because of the relationship between the building owner and the RH&C contractor, the monitoring data is not anonymized. Similarly, as part of an incentive program, an M&V program manager may request that operating data be made available for analysis. Because the M&V program manager has a business relationship with the building owner, the MSP data policies should enable sharing of operating data with third parties, upon consent of the building owner. The oTherm framework will not include personally identifiable information (PII) but will have a unique system identifier so that data can be traced back to the system through the appropriate third-party entity.

RECOMMENDED BEST PRACTICE (DATA MANAGEMENT):

- For each monitoring system, identify the set of data elements that align with the appropriate oTherm Data Model (e.g. GSHP).
- Develop and document the schema by which the data elements are stored. Systems that do not use a fixed data schema (e.g. Web Energy Logger) are not compatible with the oTherm framework.
- Develop and document data use policies. Identify the data owner and establish policies that enable the data owner to allow the MSP to share data with M&V program managers, subject to appropriate policies to protect privacy of data owner.

Energy Measures

Energy measures are central to the performance assessment of renewable thermal technologies. One view of performance is efficiency – a measure of the ratio of the energy output to the energy input. The Coefficient of Performance is the primary metric by which heat pump equipment is rated under well-controlled conditions, like the miles-per-gallon

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[2] Data is received as a JSON object as defined in Device-level data dictionary. The oTherm team may provide some assistance to MSPs converting their traditional data 'dumps' into the proper format.

metric in automobiles. Because the installed performance of a heat pump may vary from rated value, as with MPG in automobiles, other metrics of performance may be more appropriate, such as the Seasonal Performance Factor (e.g. SEPEMO).

Studies that focus on SPF will often rely upon metering equipment. Metering is focused on a specific energy flow (electrical or thermal) that uses a meter specifically designed for that energy usage and complies with appropriate standards for manufacturing, labeling, and use. The primary purpose for which meters are designed is to bill for energy usage. Using meters to assess performance of a renewable thermal system requires additional considerations to ensure that the meter is appropriate to meet the objectives.

Monitoring is broader in scope and aims to capture a diverse set of information that collectively will lead to insight into the performance of a renewable thermal systems. In the context of the oTherm framework, performance is viewed as a measure of the health of an individual system as measured by its operation relative to design and its ability to meet customer needs.

The primary purpose of the oTherm project is to develop a framework for collecting, curating, and disseminating data that can be used to assess performance rather than developing specific metrics of installed performance. The best practices for energy measures are then aimed at the types of measurements that are typically collected when assessing installed performance of renewable thermal technologies. Recommended uses of data is addressed in oTherm Best Practices for Data Users.

Energy input

Renewable thermal technologies use one or more energy sources to produce the delivered energy. For biomass systems, the energy inputs include the biomass fuel and a small electrical usage of mechanical equipment. Heat pumps use electricity to run compressors and, depending on the type of heat pump, some combination of pumps and fans. Heat pump systems are also often equipped with a backup electrical resistance heater to either supplement the heat delivered from the heat pump or to provide emergency heat in the event of malfunction.

Some heat pump systems (e.g. air-source heat pumps in very cold climates) serve the heating load during the shoulder months and rely on other equipment during the coldest part of the year.

RECOMMENDED BEST PRACTICE (ELECTRICITY MEASURES): When measuring electricity input, use metering technology that can capture minute-resolution electrical demand.

- If using an electric meter with pulse output, a high pulse rate (0.2 – 2 W·hr per pulse) is recommended. Record both pulses and time elapsed since previous reading to convert to units of watts.
- Alternatively, use a current transducer to measure instantaneous amperage (volt-amps).
- If not included as part of equipment power, provide a separate measure of auxiliary heat.

Thermal energy production

Essential to assessing the performance of a renewable thermal technologies is obtaining a measure of the thermal energy produced. Unfortunately, this is also one of the most difficult measurements to make, rife with uncertainty and measurement error.

Ground Source Heat Pumps

When measuring heating and cooling delivered by a ground source heat pump (GSHP)[3], the recommended method is to measure the thermal exchange with the ground loop source (geoexchange), the electricity usage of the compressor, and auxiliary heating elements, if present.

Direct measurement of the source side geoexchange is obtained by measuring the entering and leaving water temperatures as well as ground loop flow rate. The temperature difference is then multiplied by flow rate and the heat capacity of the heat conveying fluid. When practical, fluid temperature measurements should be made in thermal wells. For pipes sizes typical of residential installations (2 inches and smaller), on-pipe measurements are acceptable provided that (1) the external location is noted in monitoring system specification (2) the on-pipe sensor has a good thermal contact with the pipe and is insulated from ambient temperature. Temperature sensor errors shall also be reported for monitoring system. Measurement bias associated with on-pipe measurements can be corrected for as part of data analysis.

Ground loop fluid flow measurements are also often necessary for calculation of geoexchange and as variable speed pumps are becoming more common. In some cases, where a fixed pump speed is used, it is reasonable to use a constant flow rate. When measuring flow, care

[3] Applies also to ground water heat pumps (GWHP)

must be taken to use the appropriate flow sensing technologies. Sullivan et al. (2011) provide an excellent overview of flow sensing metering technologies, including theory of operation, placement of the sensors, and accuracy considerations. When the monitoring system incudes flow sensors, the method, accuracy, and location of flow sensors is to be included as part of the monitoring system specifications.

RECOMMENDED BEST PRACTICE (GSHP):

- The minimum operating data for GSHPs includes electricity consumption of heat pump(s)[4].
- When measures to compute geoexchange are obtained, they should be stored by the MSP and reported to oTherm as separate fields (e.g. EWT, LWT, and Q_f).
- Reporting locations and accuracies of measurement devices as characteristics of monitoring system (see Appendix A) improve data usability.

Heat Meters

In some facilities with hydronic systems, the thermal exchange with the ground or building may be measured by a heat meter. Heat meters will typically report heat transfer as a cumulative energy (e.g. BTUs or Watt-hours). As addressed in more detail in Heat Meters for RH&C Technologies White Paper, Practices, some heat meters have only one register and record the absolute value of energy flow. For GSHP systems, this creates a problem differentiating between heating and cooling and requires that supplemental recording of the entering and leaving water temperatures so that sign of heat transfer can be inferred over each time interval.

RECOMMENDED BEST PRACTICES (HEAT METERS): When using a heat meter as part of a monitoring system:

- For systems that heat and cool, use a heat meter with two registers that differentiates heating from cooling, or post-process based on source and return fluid temperatures.
- For each heat meter, report accuracy temperature and flow rate measurements.

[4] Additional facility data regarding the equipment manufacture/model numbers and square feet of conditioned space is addressed in separate document.

Air Source Heat Pumps

While the oTherm project focuses mostly on GSHP technology, some potential performance metrics apply to both GSHP and ASHP systems. In the initial oTherm release, ASHP systems will use the same data dictionaries as GSHP systems that include fields for electricity consumption of the compressor and auxiliary heat, if powered separately. Future releases of oTherm are likely to include a separate data dictionary for ASHP technologies that include additional fields specific to the technology.

RECOMMENDED BEST PRACTICE (ASHP):

- Like GSHPs, the minimum data for ASHPs includes electricity consumption of heat pump(s) with equipment and facility data reported as part of facility level data model.
- For systems that include embedded sensors, document locations and accuracies of sensors.

Proxies

Proxy measures of geoexchange are becoming common among states as they include thermal energy in renewable portfolio standards. In New Hampshire, for systems less than 13 tons, thermal energy produced is calculated from measured runtime and the nameplate (part load) COP for the heat pump equipment. Massachusetts has also developed proxy methods for thermal energy produced from GSHP and ASHP systems. The Massachusetts methods use the source temperature (EWT for GSHP and OAT for ASHP) and the electricity consumption of the heat pump along with temperature-dependent heat pump performance data.

RECOMMENDED BEST PRACTICE (PROXIES):

- For GSHPs, the minimum operating data should include (1) electricity consumption of heat pump(s) and (2) record of ground loop supply and return temperatures.
- For ASHPs, the minimum operating data should include (1) electricity consumption of heat pump(s) and (2) record of outdoor air temperature.
- For all RH&C technologies, the equipment model number(s) and square feet of conditioned space should be provided as part of facility-level data.

Timestamps

Correct interpretation of monitoring data is very dependent on each record having the correct date and time so that the analyst can synchronize events, such as outdoor weather conditions and building occupancy patterns, to the local time. Also, because monitoring system are recording data continuously, changes in local time due to Daylight Savings can complicate data interpretation. To overcome both of these challenges, monitoring systems should record timestamps of individual records in a continuous manner that is time zone aware. This can be accomplished by either recording time in Coordinated Universal Time (e.g. `'2014-02-07T16:14:00Z'`) and insuring the Time Zone attribute is included part of the facility information, or by recording timestamps as a datetime with offset (e.g. `'2014-02-07T12:14:00-04:00'`).

RECOMMENDED BEST PRACTICE (TIMESTAMPS): Time should be recording in a manner so that local time can be reliably determined, either UTC with Time Zone as a separate attribute or as a Time Zone aware datetime object. In either case, formatting of timestamps should follow ISO 8601[5].

Sensor metadata

With few exceptions, RH&C performance studies have not adequately documented the methods by which measurements are made or the accuracy of the measurements. This greatly limits the usefulness of the data for assessing system performance. The oTherm technical documentation (device-level data dictionary) detail the metadata that is required to add a new monitoring system to the oTherm framework. These are summarized here:

RECOMMENDED BEST PRACTICE (SENSOR METADATA):

- Report accuracies as either percentage of reading or as absolute error, according to sensor specifications. For example, a flow sensor that reports a "2% error of full scale" and has a maximum flow rate of 15 gpm, the error should be reported as ±0.30 gpm. Temperature measurements should be always be reported as absolute error (e.g. ± 0.5 °F) and not percent reading.
- The location of the sensor may be important for data interpretation. For example, on-pipe temperature sensors are prone to bias even when insulated. Location options are provided in the oTherm technical documentation.
- If the characteristics of one or sensor changes, a new monitoring system should be specified oTherm database.

Reliability of communications networks

Assessing the installed performance of RH&C technologies relies heavily on ongoing measurements of operating conditions. Continuity of data enables the analyst to assess

[5] ISO 8601 : 1988 (E), Data elements and interchange formats - Information interchange - Representation of dates and times.

several important metrics such as runtimes, energy consumed and delivered, duty cycle patterns, and operation under extreme weather conditions. Interruptions in data collection arise from disconnecting reporting devices from the local network and interruptions in the network services to building. The former may be due to equipment being unplugged and the latter to power outages. Efforts should be made to insure reliable communications and, when practical, store data locally during service outages.

RECOMMENDED BEST PRACTICE (COMMUNICATIONS NETWORK):

- Monitoring systems should have established methods for remote data collection using either a dedicated device (such as cellular modem) or an internet gateway that is part of building network.
- When practical, monitoring systems should be capable of storing data locally during times of communication disruption and uploading buffered data once the connection is restored.
- Monitoring systems should automatically notify users by text or email if their device fails to report for a specified period of time (e.g. 1 hour).

Data Transfer

A key element of the oTherm framework is the regular updating of operating data to the oTherm database instance from the monitoring system provider (MSP). Ideally, the data transfer will be performed automatically using the oTherm API (under development). Under some circumstances, and for limited number of systems, operating data can also be uploaded to the oTherm instance through a manual upload of data that is dumped to a comma separated variable file, provided this is done regularly and the csv structure is consistent.

Each MSP will have a unique identifier for a monitoring system (e.g. a MAC address of the internet-connected device). At the discretion of the MSP, and depending on privacy concerns, the oTherm instance may use the MSP identifier (MAC address) to associate the operating data with a piece of equipment or the M&V manager will provide a uuid to the MSP for each system, enabling an additional level of anonymity.

RECOMMENDED BEST PRACTICE (DATA TRANSFER):

- Time series operating data stored by an MSP should be amenable to automated transfer using a unique identifier as reference for the equipment being monitored.

References

Parker, S. A., Hunt, W. D., Stoughton, K. M., Boyd, B. K., Fowler, K. M., Koehler, T. M., Sandusky, W. F., Sullivan, G. P., & Pugh, R. (2015). *Metering Best Practices: A Guide to Achieving Utility Resource Efficiency, Release 3.0*. https://doi.org/10.2172/1178500 PDF

Sullivan, G., Hunt, W. D., Pugh, R., Sandusky, W. F., & Boyd, B. K. (2011). *Metering Best Practices, A Guide to Achieving Utility Resource Efficiency, Release 2.0*. https://doi.org/10.2172/1028083 PDF

Appendix: Adding new Monitoring System to oTherm

The Device-Level Data Dictionary has been implemented in a web-based application using the Django framework. Django applications typically have an administrative interface that provides users with Staff privileges more direct access and ability to enter data into data tables. Users with 'user' privileges access a slightly more refined (frontend) interface that enables them to perform management functions such as adding sites, RH&C equipment, and specifying the monitoring system that is deployed on an individual piece of equipment. We anticipate a third level of access for 'viewers' that can query and download aggregated data.

This Appendix provides a brief overview of the process for adding a new monitoring system to the oTherm database. Once a monitoring system is added to the database, it is available for users to select in setting up a site.

A monitoring system can be added to the oTherm database through an online process that begins with Monitoring System Registration button on the frontend home page (Figure A1).

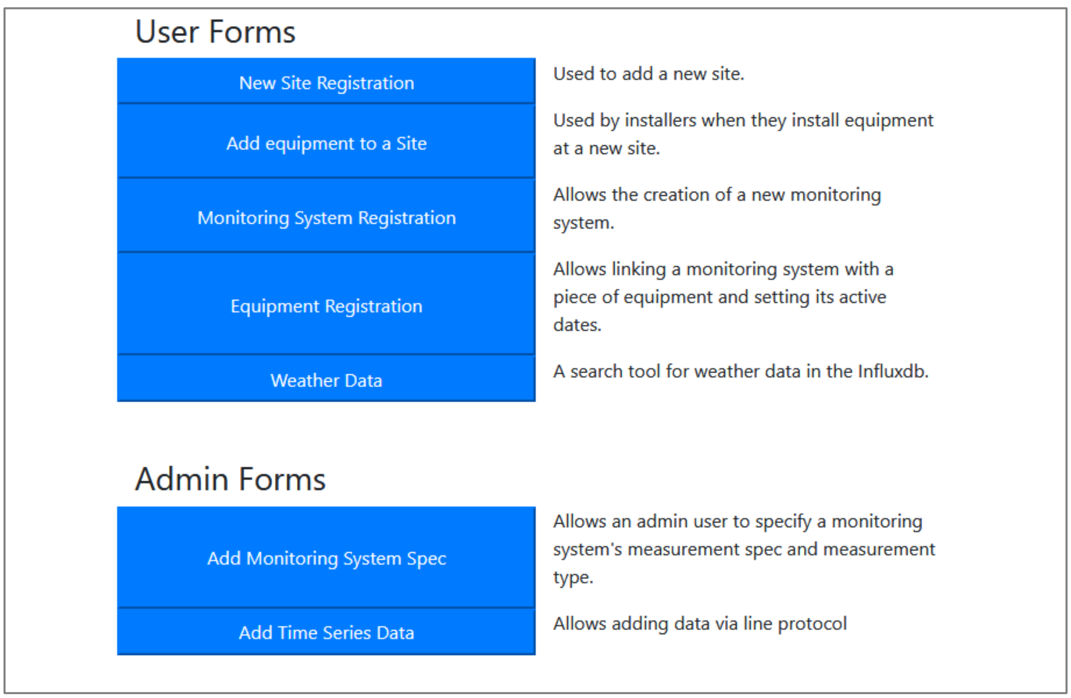


Figure A1. User interface on oTherm homepage.

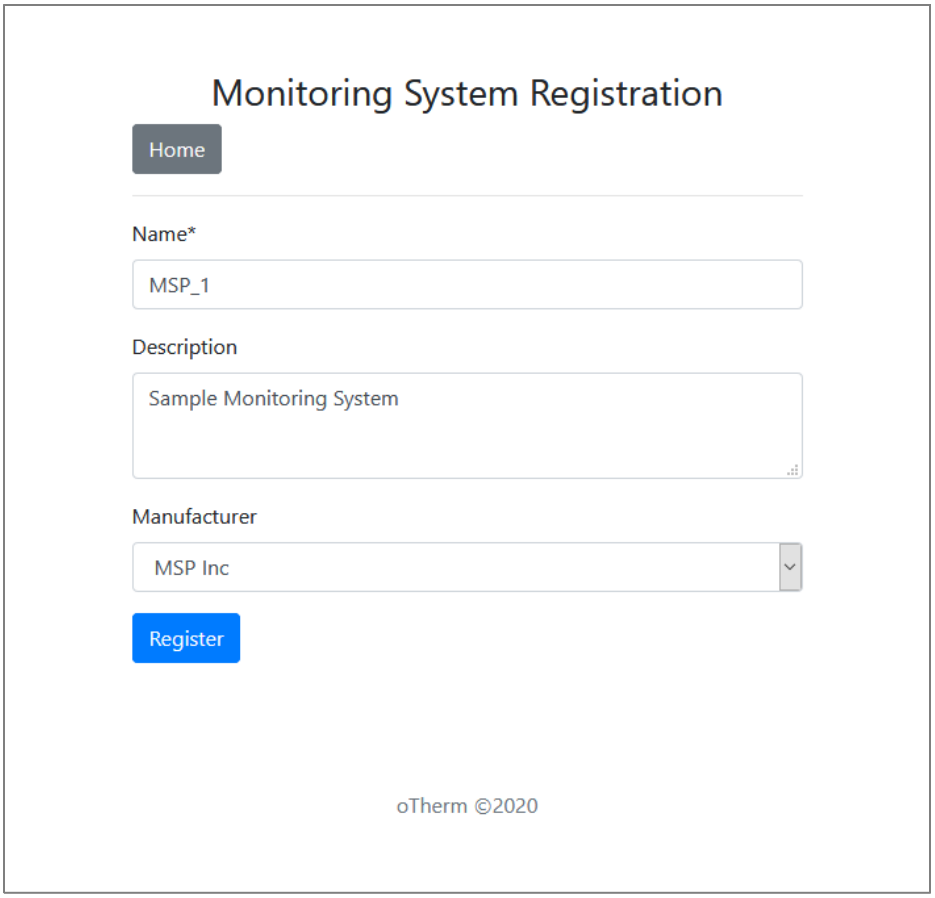


Figure A2. Monitoring system registration begins with defining a name, description, and manufacturer.

In this example, the monitoring system name is 'MSP_1' and the manufacturer is the hypothetical firm 'MSP Inc'. We expect that in the final version, monitoring system names will follow a structure to help identify the correct monitoring system during site setup.

When the monitoring system is first defined it has no measurements attributes (Figure A3). These attributes are added through the 'Edit System Spec' button.

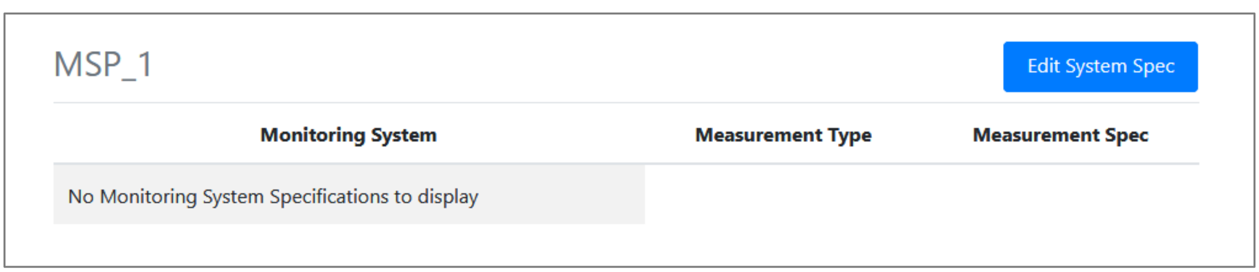


Figure A3. The measurement specs for each monitoring system are displayed. Upon initial creation of a monitoring system, it has no specification. These are added through 'Edit System Spec'.

The user selects a set of Measurement Specifications that are part of the Monitoring System being added. In this example, the monitoring system has four measurement points: auxiliary heat (AuP), heat pump power (HPP), entering water temperature (EWT), and leaving water temperature (LWT). The names of each specification indicate characteristics about the measurement that are stored in separate tables. For example 'AuP VA 8% HP' stands for auxiliary power (AuP) using a volt-amp method (VA) with 8% error and the sensor is located in the heat pump (HP).

The measurement specifications for the monitoring system are selected and then add (using > button) to the system, as illustrated in Figures A4 and A5.

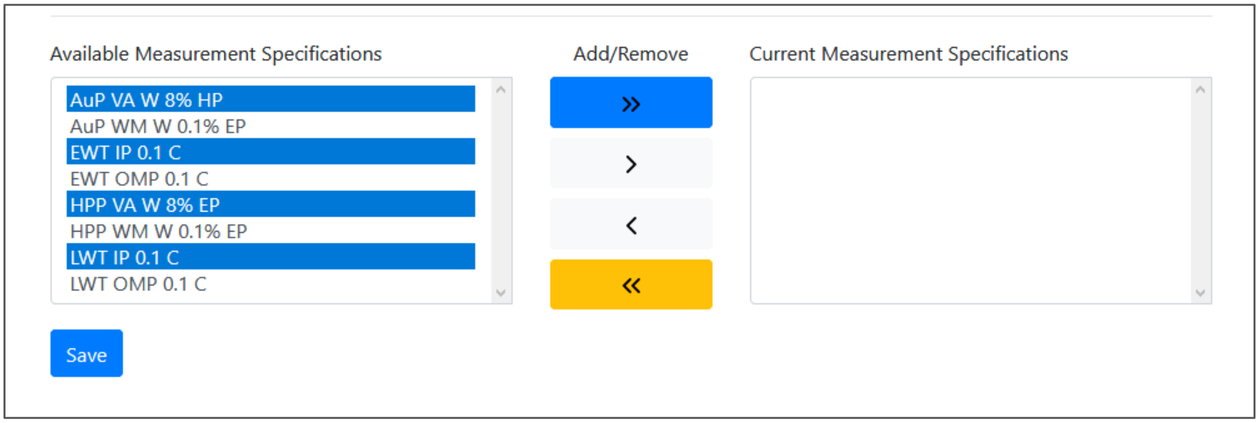


Figure A4. Measurement specification are selected from prepopulated list.

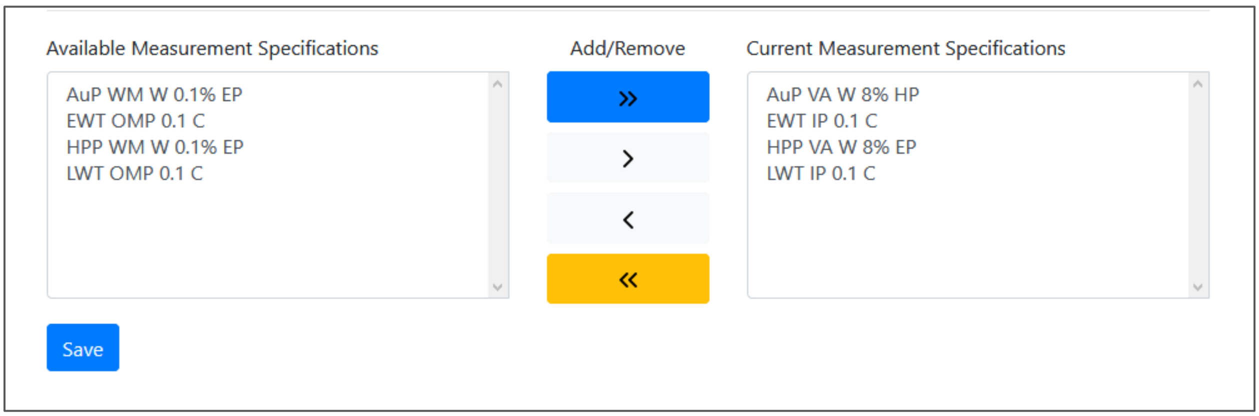
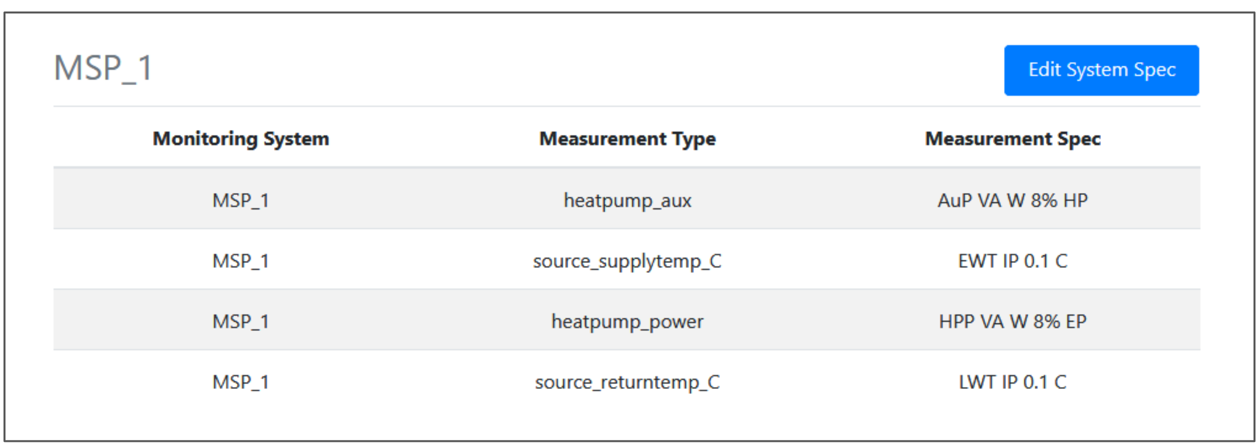


Figure A5. The selected measurement specifications are added to the monitoring system using the '>' button.

Once the measurement specifications are added, the user returns to the previous screen showing the monitoring system and its measurement specifications (Figure A6)


MSP_1

Edit System Spec

Monitoring System	Measurement Type	Measurement Spec
MSP_1	heatpump_aux	AuP VA W 8% HP
MSP_1	source_supplytemp_C	EWT IP 0.1 C
MSP_1	heatpump_power	HPP VA W 8% EP
MSP_1	source_returntemp_C	LWT IP 0.1 C

Figure A-6. Once measurement specifications are added, they are summarized in table of Monitoring Systems (compare with Figure A3)

The measurement specifications each have a set of attributes that define the type of measurement (one of 16 defined in Data Dictionary), the location of the measurement, and the accuracy of the measurement. In the name of the measurement specification, these are included using shorthand notation and are formally defined in the appropriate database tables. The use can expand on any measurement specification to expose the characteristics in more detail. As illustrated in this example, monitoring systems can report in a variety of units and oTherm will convert to SI units for storing in database. Retrieval of data can also be done in SI or Imperial units, with oTherm making necessary conversions.

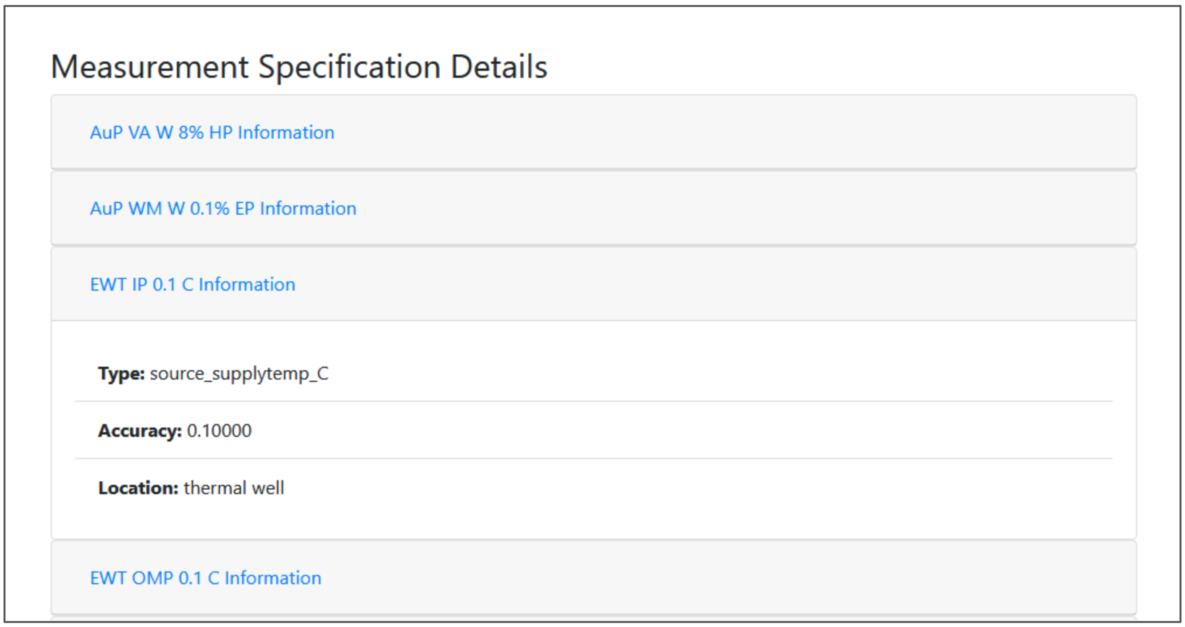
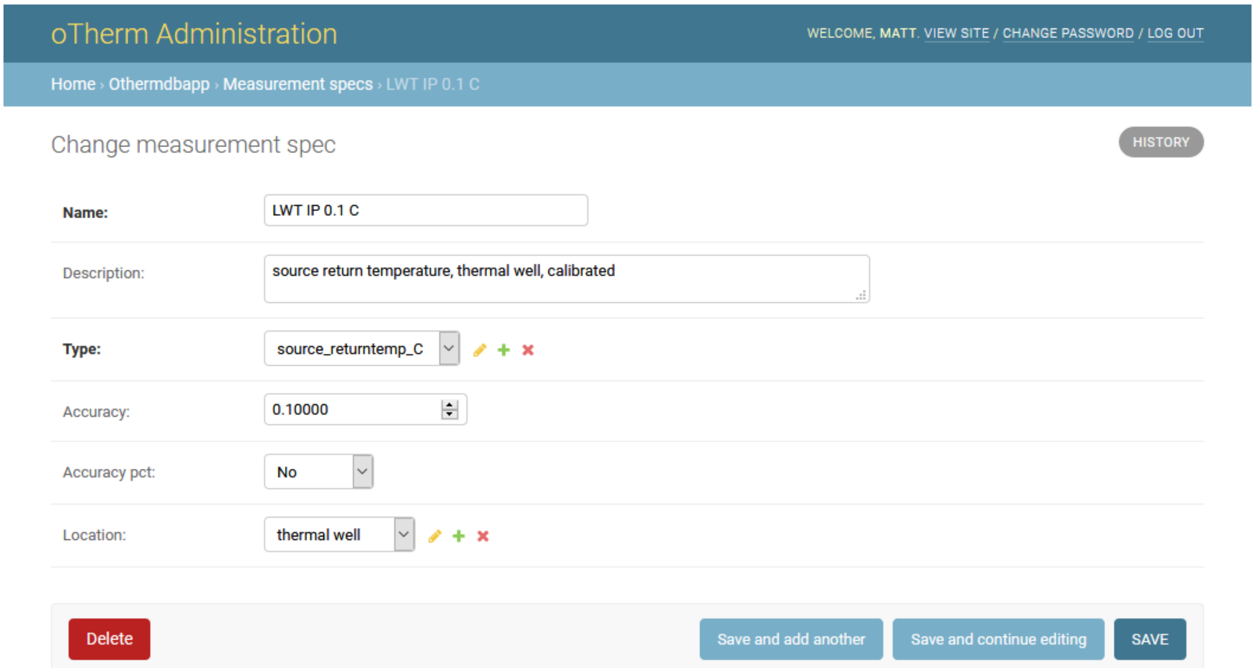


Figure A7. Measurement specification details can be exposed to ensure proper specification is selected.

While users have the ability to create new monitoring systems from combinations of different measurement specifications, the measurement specifications are added the oTherm database through the system administration interface, requiring 'Staff' privileges (Figure A8).



FigureA8. Administrative interface for adding new measurement specifications.