oTherm Device-Level Data Model Specification for Ground Source Heat Pump (GSHP) Systems

Version 1.1

This document is part of a research project by the New York State Energy Research and Development Authority (NYSERDA), the University of New Hampshire, and Yale University. Funding for the project is provided by the US Department of Energy, Office of State Energy Programs (DE-EE0008619). Financial support has also been provided by the Renewable Thermal Alliance.

oTherm Project Task 1:
    Device Level Data Dictionary Specification

J. Matthew Davis and Timothy Carlin
University of New Hampshire

February, 2020

Table of Contents

Acknowledgements and Disclaimers

Acknowledgement:
This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under the Office of State Energy Programs Award Number DE-EE0008619.

Disclosure:
The UNH Principal Investigator on the oTherm project (Davis) is co-founder of Ground Energy Support LLC and retains a financial interest. The current oTherm grant, as well as his prior DOE-STTR grant, are subject to UNH policies on Financial Conflict of Interest in Research and overseen by the UNH Office of Research Integrity.

Version History

November	2019:	Draft distributed to oTherm Advisory Team
February	2020:	Revisions made based on 11/14/2019 workshop
November	2021:	Editorial revisions

Introduction

The collection and analysis of data from building systems using renewable thermal technologies (RTTs) has been recognized as high priority in addressing a number of market barriers. The current effort focuses on ground source heat pump (GSHP) technology as a specific use case with a goal of developing a general framework that can be readily applied to other RTTs.

For GSHP systems (also referred to as geothermal heat pumps), the market barriers of high up-front cost and lack of confidence in the technology have been recognized for some time (e.g. DOE, 2012). The recent GeoVision report released by the Department of Energy (DOE, 2019) recognizes the potential of GSHP technology to provide heating and cooling to an equivalent of 28 million homes by 2050 (14 times the 2 million today). The GeoVision report also reaffirms the lack of awareness, high cost, and perceived risks continue as market barriers and note the need for a standardized and reliable way of quantifying benefits.

Facing similar challenges twenty years ago, the solar photovoltaic (PV) industry, led by the SunSpec Alliance and National Renewable Energy Lab, developed the open Solar Performance and Reliability Clearinghouse (oSPARC). The oSPARC data clearinghouse (SunSpec, 2013) has, in part, contributed to the development of new business models, lowered the cost of solar PV installation, and stimulated growth in the solar PV market.

The development of the open Renewable Thermal Data Clearinghouse (oTherm) was initiated through discussions within the Renewable Thermal Alliance and follows strategy similar to the SunSpec Alliance process developed for oSPARC.

The objective of this document is to document the Device-level Data Model, that is one component of the oTherm database. The objective of the oTherm project is to standardize the collection of operating and site data from GSHP systems, not the methods or accuracies required. Users of the data will be responsible for interpreting the data given the limitations that may stem from inaccuracies in the data reported.

Overview of oTherm Data Models

The underlying data architecture of oTherm is being be developed as two complementary data models consisting of three types of data: high-resolution operating data, medium-resolution weather data, and static building data (Figure 2).

The first data model focuses on time series data collected from data acquisition systems installed on (or in) the renewable thermal system. This is referred to as the Device-level Data

Model (DDM) and is the focus of this report. While the bulk of the data will be time series data, the DDM will also include metadata that is necessary to organize and interpret the time series data. The time-series data for weather conditions will be added as part of Task 2. The Facility-level Data Model (FDM), also part of Tasks 2 and 3, will focus on the static characteristics of the renewable thermal system, including the building, its usage, and other necessary characteristics.

So that oTherm data can be used for multiple use cases in the future, a set of Best Practices documents will be developed as guides for both data providers and end users. The Best Practices documents will provide guidance on the characteristics of monitoring systems that are compatible with oTherm, recommendations for placement of individual sensors relative to the renewable thermal equipment, and specification of sensor accuracies, and example performance metrics that might be calculated from oTherm data.

For the initial release of oTherm, the data models will focus specifically on the measurements expected for a ground source heat pump (GSHP) system, which will then serve as a template for other RTTs. Inclusion of elements in the data model are determined in consultation with the oTherm Advisory Team and based on (a) potential to provide insight into system performance and (b) the likelihood that they will be of sufficient quantity to be of value in the final database.

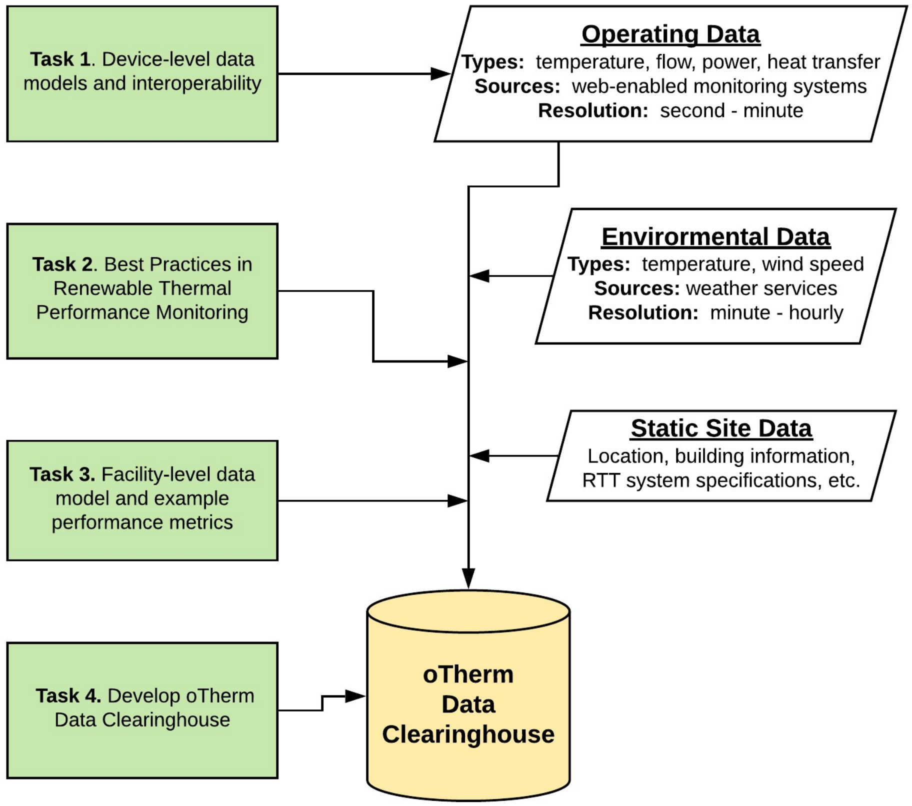

Figure 1. oTherm development tasks and data models.

Monitoring Service Providers

oTherm will rely upon the cooperation and coordination among multiple entities that provide web-based monitoring services. It is expected that these will be dominantly heat pump manufacturers that either have web-based monitoring systems (such as WaterFurnace) or are developing them (such as Dandelion, Bosch, and others). It is recognized that the monitoring service providers (MSPs) use their systems for a variety of services with both end users and installers. oTherm will operate independently from these relationships and not interfere with these ongoing services. We envision that oTherm will access operating data through an application programming interface (API) (Figure 3). The oTherm project will specify the format of the API response and either assist data providers in developing tools to perform the necessary conversions prior to transmission or perform necessary conversions before storing in database.

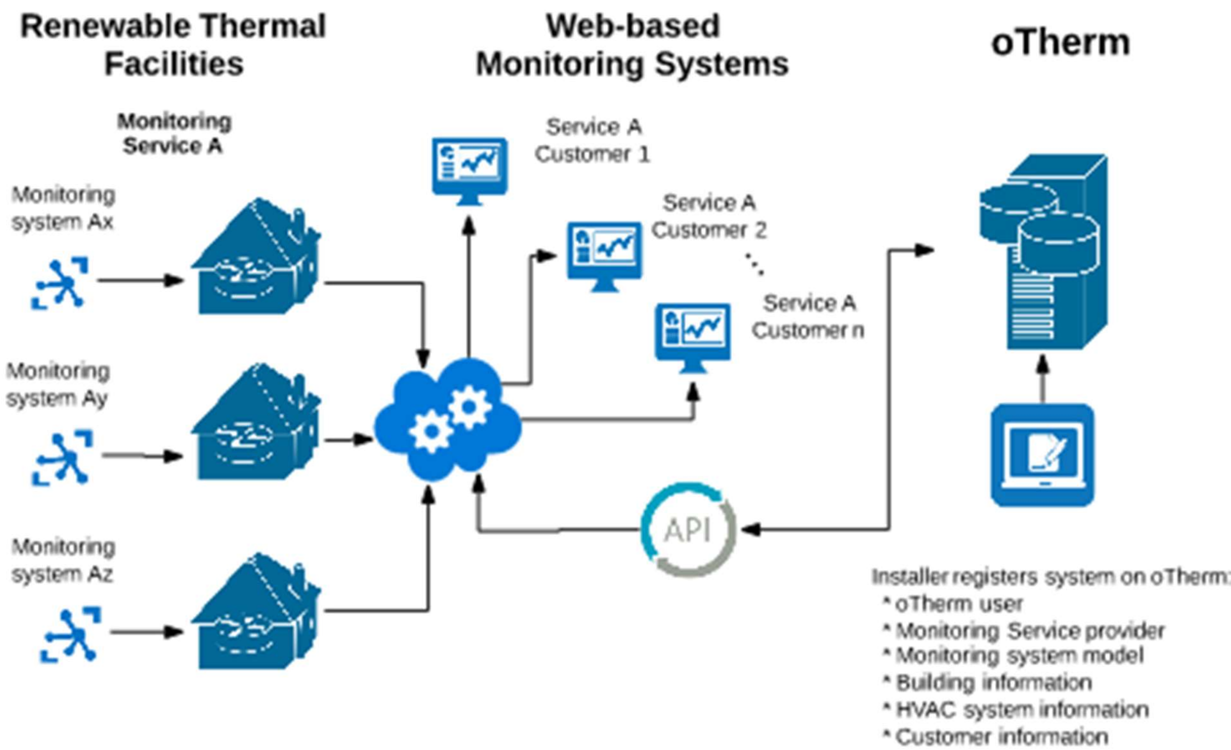

Figure 2. Schematic illustration of relationship between web-based monitoring systems and oTherm (weather data not shown).

Process and Participants

To ensure that the necessary data elements are captured, that data meet the needs for potential oTherm users, and that technical specifications meet appropriate industry standards, an oTherm Advisory Team has been established. Additional technical input on GSHP system monitoring is being provided through the Experts Meetings of the IEA Heat Pump Technologies Annex 52 project to which Principal Investigator Davis is a member and lead author the project's Instrumentation and Data Guideline document.

Data licensed to UNH by Ground Energy Support LLC will be used for the development and testing of data models and interoperability. Data from other service providers will be included as made available to the oTherm project team. The Symphony data used in the recent NYSERDA study (CDH, 2017) may also be used, pending approval of NYSERDA and WaterFurnace.

Measurement Types

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 allow for easy use once the characteristics of a monitoring system are specified.

This section reviews the different kinds of measurements often associated with RTT systems and the characteristics that will then be specified in the Device-level Data Model. The specific data elements and the organization of Device-level Data Model is addressed in the following section.

Timestamp

Time of record will be reported in UTC using a DateTime format (e.g. ISO 8601). Each site will have time zone attribute. It is expected that the monitoring system will provide reasonably synchronous records. For minute-resolution data, network latency issues are expected to be minimal[1].

Electric Consumption

The method of measurement shall be included as an attribute. Common options include (a) measuring the True RMS power using a watt-meter (`trms`), (b) measuring both volts and amps and multiplying together (`mv_ma`), (c) assuming a constant voltage multiplied by the measured amperage (`cv_ma`), and (d) using heat pump specifications to model the power consumption as a function of heat pump operation (`model`). Each of these methods has different accuracies, approximately 1%, 5%, 10%, and 15%, respectively.

Temperature

The method of measurement shall be included as an attribute consisting of technology and accuracy. Temperature measurement methods include, but are not limited to, digital sensors (e.g. `DS18B20`), negative temperature coefficient (`NTC`) thermistors, and platinum resistive temperature devices (`RTD`). The accuracy of the temperature measurement shall be reported as a magnitude in degrees Fahrenheit, for example "0.5" for ±0.5 °F. In addition, for temperature measurements of fluids in pipes, the location of the temperature measurement shall be specified as either in a thermal well (`in_pipe`) or strapped to the outside of the pipe (`on_pipe`).

[1] If sensor data are collected as part of a Building Management System with large number of sensors, network latency may be an issue.

Temperature Difference

If the monitoring device measures temperature difference, in place of or in addition to point temperatures, the temperature differences shall be reported. The accuracy of the temperature difference shall be reported according to accuracy classes used in heat meter standards (OIML R75, EN1434, C900.1, ASTM E3137/E3127M). The international standard (OIML, 2002) is referenced here as it is in the public domain. The European (EN1434), Canadian (C900.1), and United States (ASTM E3137/E3127M) standards are available for purchase. Review of the other standards suggests that they follow the same accuracy classes for accuracy as OIML R75.

The heat meter accuracy classes for temperature difference (Table 1) refer to the smallest temperature difference (ΔT_{min}) that can be measured while maintaining the Maximum Permissible Error (MPE) of 3.5%. For example, for to satisfy an MPE of 3.5% for a temperature difference of 1 degree Celsius, it is necessary for the temperature sensor pair to have an accuracy of 0.035 degrees Celsius. The greater the accuracy of the temperature difference measurement (lower Class number), the smaller the minimum temperature difference. This does not mean that temperature differences less than the ΔT_{min} cannot be measured and reported, only that measures below the minimum have an error greater than 3.5%. Because renewable thermal systems, such as GSHP systems, often have low temperature differences, it is important to quantify the accuracy of the temperature difference measurements.

Table 1. Temperature difference accuracy class used in common heat meter standards.

ΔT Class	ΔT_{error} [°C]	ΔT_{min} [°C]	ΔT_{error} [°F]	ΔT_{min} [°F]
1K	0.035	1.0	0.063	1.8
2K	0.070	2.0	0.126	3.6
3K	0.105	3.0	0.189	5.4
5K	0.175	5.0	0.315	9.0
10K	0.350	10.0	0.630	18.0

For temperature differences that are computed from individual point measurements, the accuracy of the temperature difference can also use same accuracy scheme.

For example, for a pair of sensors that are calibrated to within 0.1 ^{o}C of a common sensor, the measurement error for the temperature difference measured by the matched pair would be 0.14 ^{o}C ($\sqrt{0.1^2 + 0.1^2}$) and reported as Class 5K accuracy. For comparison, a Badger 380 BTU Meter (commonly used for high-temperature hot water systems) is equipped with RTD temperature sensors that meet the IEC751 Class B accuracy (±0.3 ^{o}C at 0 ^{o}C) resulting in a temperature difference accuracy of 0.42 ^{o}C, exceeding the Class 10K limit, suggesting a minimum temperature difference of more than 18 °F in order to have an error less than 3.5%.

This is much larger than typically encountered in GSHP systems. Heat meter product literature commonly report the accuracy of the flow sensor as the accuracy of the meter, rather than the total error. The total heat meter error is the sum of the errors attributed to the three contributing sources: flow, temperature difference, and computation.

Flow rate

When flow rates are reported, the method and accuracy of the flow meter shall be reported. Flow meter methods include (but are not limited to): vortex shedding sensors (e.g. Grundfos VFS series), multi-jet water meters, turbine meters, ultrasonic, and induction meters. The metering technology is important when interpreting flow data as the accuracy of different metering technologies may depend on the fluid characteristics, particularly when the fluid is an aqueous mixture with an antifreeze.

Table 2. Flow meter accuracy classes as a function of turndown and accuracies at minimum and maximum flow rates.

Class	Turndown	E_f at minimum flow ($q=q_i$)	E_f at maximum flow ($q=q_p$)
Class 1	10:1	1.10%	1.01%
	25:1	1.25%	1.01%
	50:1	1.50%	1.01%
	100:1	2.00%	1.01%
	250:1	3.50%	1.01%
Class 2	10:1	2.20%	2.02%
	25:1	2.50%	2.02%
	50:1	3.00%	2.02%
	100:1	4.00%	2.02%
Class 3	10:1	3.50%	3.05%
	25:1	4.25%	3.05%

The accuracy shall also be reported according to accuracy classes used in heat meter standards (OIML R75). The Maximum Permissible Error for flow sensors depends on the ratio of the permanent flow rate (q_p) to actual operating flow rate (q)[2]. Table 2 shows the range of allowable MPE for flow sensors by Class and turndown according the following equations (OIML R75-1:2002).

Class 1 $E_f = \pm (1 + 0.01\ q_p/q)$, but not more than ± 3.5 %

Class 2 $E_f = \pm (2 + 0.02\ q_p/q)$, but not more than ± 5 %

Class 3 $E_f = \pm (3 + 0.05\ q_p/q)$, but not more than ± 5 %

[2] "The permanent flow rate is the highest flow rate at which the heat meter shall function continuously without the permissible errors being exceeded.", OIML R-75:2002

Turndown is defined as the ratio of the maximum flow rate (q_p) to minimum flow rate (q_i) expressed as a ratio and is defined in Section 7.2 of OIML R75-1.

Not all facilities will be equipped with flow meters. For some heat pumps, a design flow rate may be assigned as a proxy. In these cases, the heat pump design flow rate will be included in the Facility-level Data Model and designated with an accuracy class of '`design`'.

Heat meters

In some facilities, the thermal heat 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. Watt-hours). As will be addressed in more detail in the Best Practices documents, some heat meters have only one register and record the absolute value of energy flow. For GSHP systems, this requires post-processing to differentiate between heating and cooling and requires that supplemental recording of the entering and leaving water temperatures so that the sign of heat transfer can be inferred over an interval. The method of measurement shall be included as '`heat_meter`' an attribute with the accuracies of the temperature difference and flow sensor reported as described above.

Data Dictionary

Device-level Data Elements

The Device-level Data Model for GSHPs focuses on minute-resolution operating data and will typically include three types of data fields: temperature, flow, and power. Inclusion of elements in the data model will be determined based on (a) potential to provide insight into system performance and (b) the likelihood that it will be of sufficient quantity to be of value in the final database. The initial set of primary data elements is summarized in Table 3. Being time-series data, operating data in the DDM is expected to be stored in a NoSQL database designed specifically for time series data[3].

Except for heat meter readings, readings shall be reported as instantaneous values on approximately 1-minute intervals. Heat meter readings shall be reported as cumulative energy (W-hours) since the previous record.

In addition to the 16 primary data elements, it is possible to include data elements that are combinations of one or more of the 16 data elements in Table 3. For example, if the electrical power measurement for a heat pump compressor includes the ground loop circulating pump, an additional data element can be added to the database. This would be true for other

[3] For prototyping, the oTherm project team is using the open-source InfluxDB, licensed under the MIT License. (https://github.com/influxdata/influxdb)

combinations as well, such as when the auxiliary heat is powered by the same circuit as the load side distribution fans.

Table 3. List of primary device level data elements.

	Data Element	Units	Name	Type
-	Timestamp	UTC	Datetime	time
1	GSHP compressor	W	heatpump_power	electric power
2	Auxiliary back up heat (Electric)	W	heatpump_aux	electric power
3	Entering water temperature	ºF	source_supplytemp	temperature
4	Leaving water temperature	ºF	source_returntemp	temperature
5	Source temperature difference	ºF	source_tempdiff	temperature difference
6	Source fluid pump power	W	sourcefluid_pump_power	electric power
7	Source fluid flow rate	gpm	sourcefluid_flowrate	fluid flow rate
8	Load circulating pumps/fan	W	load_pumpsfans	electric power
9	Load supply temperature	ºF	load_supplytemp	temperature
10	Load return temperature	ºF	load_returntemp	temperature
11	Load temperature difference	ºF	load_tempdiff	temperature difference
12	Thermostat set point	ºF	tstat_set	equipment state
13	Thermostat temp	ºF	tstat_temp	equipment state
14	Percent full load	%	compressor_stage	equipment state
15	Heat meter load	BTU	loadside_heat	thermal energy
16	Heat meter ground loop	BTU	sourceside_heat	thermal energy
17	Heat flow ground loop	BTU/hr	sourceside_heatflow	thermal power

Data Schema Tables

The Device-level Data Model consists of a time series of point measurements that are obtained by a monitoring system attached to an individual heat pump at a given facility at a known location. The measurement values are stored in oTherm as a time-series object using a database architecture intended for time-series data. Time-series data will consist of a timestamp and one or more columns with standardized field names.

Each time series object will be tied to a piece of RTT equipment (e.g. a heat pump) that will have a universally unique identifier (`uuid`[4]) in oTherm. The heat pump equipment will be part

[4] A universally unique identifier is a 128-bit number represented as a 32 hexadecimal digits. They are beneficial as database keys as they are unique and permanent. Traditional database keys are integer values generated sequentially and accessing records requires permanence in the in the database schema. Because oTherm is likely to evolve, the use of uuid values as some database keys will more readily allow for modifications to the schema.

of a facility and will be equipped with a monitoring system. This document focuses on the data elements that can be expected to be part of the time series data and the organization of the information about the measurements and the monitoring system[5].

The proposed database relationships between the equipment, the monitoring systems, and the measurements constitutes a 'data schema', as illustrated in Figure 4. The schema is explained further below and followed by an example.

In describing the rationale for the data schema, it is helpful to begin with the measurements to be reported to oTherm[6]. For each measurement, it is necessary to know the type of measurement (Table 3) and four characteristics of the technology used to obtain the measurement: (1) the sensor technology, (2) the type and units of measurement reported, (3) the accuracy of the measurement, and (4) the location of the measurement.

Each different measurement is specified in the `measurement_spec` table. While there are relatively few types of measurements, a unique measurement may differ in the technology used to obtain the measurement, the location of the measurement, and/or the measurement accuracy. For example, because there are four methods that can be used to measure compressor power, each with a different accuracy, there will be four (or more) entries in the `measurement_spec` table for compressor power. Likewise, fluid temperatures can be measured in a thermal well (in-pipe) or affixing a sensor to the

[5] Specifying the data model for the heat pump equipment and facility will be addressed in Tasks 2 and 3 and part of the Facility-level Data Model.

[6] Data shared with oTherm is likely to be a subset of the data collected by the monitoring system.

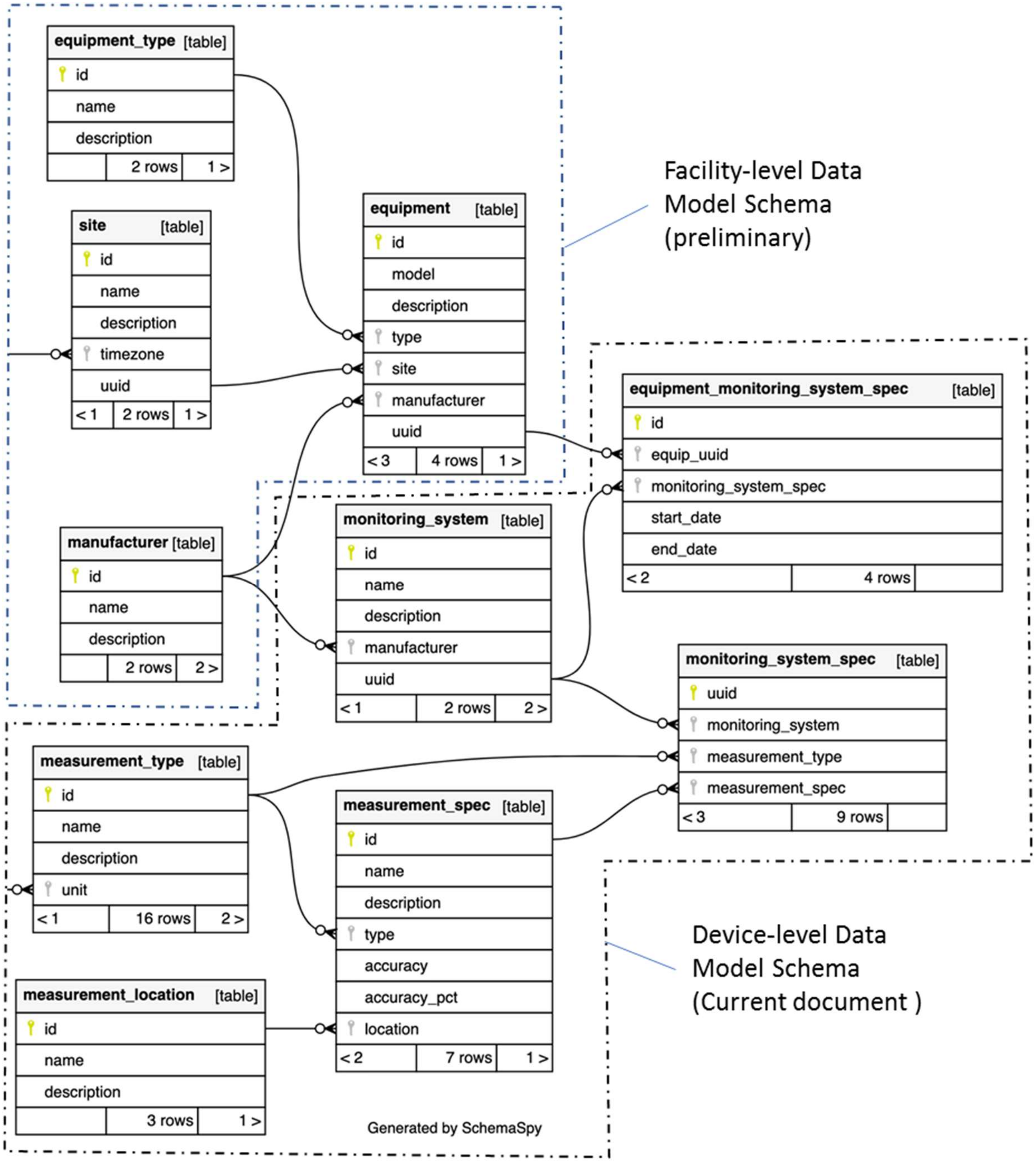

Figure 3. Schematic illustration of static oTherm data tables and relations. Measurement unit and timezone tables not shown. Time series 'history' data not shown. Schematic generated with SchemaSpy (https://schemaspy.readthedocs.io/en/latest/overview.html).

outside of the pipe (on-pipe). The location of measurement is referenced in the `measurement_location` table. While we expect to standardize measurement units, they must also be specified and are referenced in the `measurement_units` table (not shown in Figure 4), consisting of the id, unit name, and a description.

While there are many variations in the types of measurements, their accuracy, and location, these characteristics are relatively uniform for a given monitoring system. A 'monitoring system' is defined as a collection of measurements and their associated attributes. Each monitoring system is given a universally unique identifier (`uuid`). The measurements obtained from a given monitoring system are defined in the `monitoring_system_spec` table that consists of all measurements performed by the monitoring system, including the measurement type (i.e. a subset of the 16 data elements listed in Table 3) and the measurement specification as referenced in the `measurement_spec` table discussed above. Once a monitoring system is defined in the database, all of the characteristics can be easily accessed from the `monitoring_system` table.

For the GSHP Device-level Data Model, a monitoring system is associated with an individual heat pump (equipment). Each heat pump is assigned a `uuid` that is then used as a means to identify the monitoring system attached (`equipment_monitoring_system_spec`). Because the monitoring system for a given heat pump may change at some point in time (e.g. a change of a sensor, a change in calibration, or an upgrade), the equipment monitoring system has attributes of a defined start date and optional end date.

The current document focuses on the Device-level Data Model and so the primary concern is the structure of the data schema necessary to adequately represent data from a heat-pump-attached monitoring system. To facilitate testing, it is necessary to introduce a preliminary framework for the static facility-level data model.

Facility-level Data Model (Preliminary)

While the requirements for static site data will be addressed in the Facility-level Data Model (Tasks 2 and 3), it is necessary to begin to develop some of the initial features so that the Device-level Data Model can be developed and tested.

It is expected that the FDM will include information about the renewable thermal equipment (e.g. heat pump capacity and model) and the site (e.g. building, ground loop characteristics). For the present purposes, these tables are populated with skeletal entries to include the necessary fields (keys) to establish relationships between the tables.

Outdoor Air Temperature (future)

The outdoor weather conditions are an important factor in the operation and performance of RTT systems. Because these data are important for all sites and a single weather observation may apply to multiple sites, it is recommended that oTherm manage the collection and storage of outdoor weather conditions on a 15-minute interval using web-based weather services. This data table and its relation to the `site` table will be established in the development of the Facility Level Data Model. It is anticipated that the `site` table will be expanded to include a weather station identifier based on the geographic location of the site in Tasks 2. While the primary interest is in outdoor air temperature, other measurements, such as wind speed, may be obtainable as well.

Example Application of Device-level Data Model

To illustrate and test the device-level data model, we have used data licensed to UNH by Ground Energy Support to create some simple examples. Two sites are used, both single family residences. One is in northeastern Massachusetts, is a closed-loop system with a single heat pump monitored by a GxTracker-Power kit with calibrated temperature sensors, current transducers for power, and no flow meter. The second is in southwestern New Hampshire, is an open-loop system with three heat pumps, monitored by a GxTracker-PowerPlus kit with uncalibrated temperature sensors, vortex shedding flow sensors, and TrueRMS power meters.

Site

First, each site is represented with a name, description, uuid, and time zone. For the tables below the last four digits of the 32-character uuid are shown for simplicity.

Table 4. Site table including information about the site, minimal at this stage and will be developed further in Tasks 2 and 3.

id	name	description	uuid (last 4)	Time zone
1	Westford	Single heat pump system	69e1	America/New_York
2	Keene	Three heat pump system	a761	America/New_York

Equipment

The heat pump equipment at each site is represented in the `equipment` table (Table 5), with the types of heat pumps identified by the integer id values above are referenced to the `equipment_type` table (Table 6).

Table 5. Equipment table specifying the uuid of the heat pump equipment. Additional detail to be added in Tasks 2 and 3.

id	name	description	type	site (last 4)	manufacturer	uuid (last 4)
1	Westford HP1	Heat Pump	1	69e1	1	3caf
2	Keene HP1	Heat Pump	2	a761	1	a703
3	Keene HP2	Heat Pump	2	a761	1	ab04
4	Keene HP3	Heat Pump	2	a761	1	1889

Table 6. Equipment_type table allows for specification of different types of equipment. In this example, the closed loop system being a GSHP and the open-loop system a GWHP. Additional characteristics of the RTT equipment will be included in the Facility

id	Name	description
1	GSHP	Ground Source Heat Pump
2	GWHP	Ground Water Heat Pump

The monitoring system attached to each heat pump equipment (as designed by equipment uuid) is specified in the `equipment_monitoring_sys_spec` table (Table 7). Note that the same monitoring system is used for three of the heat pumps. Each has a specified start_date and should a change in the monitoring system be made, a new entry would be added for the same equipment but with the start_date as the date on which the change was made.

Table 7. Equipment_monitoring_spec table.

id	equip_uuid [last 4]	monitoring_sys_uuid [last 4]	start_date	end_date
1	3caf	6611	2013-12-10 19:00:01	Null
2	a703	9042	2015-01-11 19:00:01	Null
3	ab04	9042	2015-01-11 19:00:01	Null
4	1889	9042	2015-01-11 19:00:01	Null

Monitoring Systems

The monitoring systems referenced in Table 7 (by uuid) are specified in the `monitoring_system` table (Table 8). The ‘name’ entry in the current example is rather simple, and it will likely be beneficial to codify the naming so that it is more informative about the system and its capabilities (e.g. a model number system).

Table 8. Monitorin_system table.

id	name	description	manufacturer	uuid (last4)
1	GxTracker Power	calibrated temp, current transducers, no flow meter	2	6611
2	GxTracker PowerPlus Flow	calibrated temp, True RMS, flow meter	2	9042

Measurements

The set of measurements made by a designated monitoring system are specified in the `monitoring_system_spec` table. Each row in the monitoring `monitoring_system_spec` is a unique representation of a measurement made by a monitoring system, including the measurement type (Table 10) and reference to the measurement technology, accuracy, and location (though the `measurement_spec` id in Table 11).

Table 9. The monitoring_system_spec table.

uuid [last 4]	monitoring_system	measurement_type	measurement_spec
d222	6611	1	1
c1a5	6611	3	2
9196	6611	4	3
3a21	6611	2	4
8fe1	9042	1	5
01c9	9042	3	2
516b	9042	4	3
f0ca	9042	6	6
c7aa	9042	7	7

Table 10. Measurement_type table identify the 16 different types of measurements in oTherm.

id	name	description	unit
1	heatpump_power	GSHP compressor	1
2	heatpump_aux	Auxiliary back op heat (Electric)	1
3	source_supplytemp	Entering water temperature	3
4	source_returntemp	Leaving water temperature	3
5	source_tempdiff	Source temperature difference	3
6	sourcefluid_pump_power	Source fluid pump power	1
7	sourcefluid_flowrate	Source fluid flow rate	4
8	load_pumpsfans	Load circulating pumps/fan	1
9	load_supplytemp	Load supply temperature	3
10	load_returntemp	Load return temperature	3
11	load_tempdiff	Load temperature difference	3
12	tstat_set	Thermostat set point	3
13	tstat_temp	Thermostat temp	3
14	ompressor_stage	Heat pump stage	5
15	loadside_heat	Heat meter load	2
16	sourceside_heat	Heat meter ground loop	2

Table 11. Measurement_spec table. Each measurement that differs in type, accuracy, or location will have a unique entry.

id	name	description	type	accuracy	percent	location
1	Compressor Power	Volt-amps	1	5.0	True	2
2	Entering Water Temp	On-pipe temp	3	0.1	False	1
3	Leaving Water Temp	On-pipe temp	4	0.1	False	1
4	Auxiliary Power	Volt-amp	2	5.0	True	2
5	Compressor Power	True RMS	1	1.0	True	2
6	Pump Power	True RMS	6	1.0	True	2
7	Source Fluid Flow Rate	Vortex Shedding	7	1.0	True	3

Table 12. Measurement_unit table to record the units of different measurement types.

id	name	description
1	W	watts power use
2	W.hr	watt-hour
3	F	degrees Fahrenheit
4	gpm	gallons per minute
5	%	percent
6	NA	dimensionless

Interoperability

oTherm is dependent upon data provided by web-based monitoring service providers (MSPs). As illustrated in Figure 1, oTherm is envisioned as serving several roles, including a platform for registration of new RTT facilities, for retrieving data from MSPs, and serving as a data portal to registered oTherm users. The build out of the necessary interfaces are to be developed as the project progresses.

Registration of new RTT facilities

New systems will be registered through an online portal through which information about the site, equipment, and monitoring system is provided, typically by a system owner or installer. Included will be the opt-in permission from the facility owner for data to be shared with oTherm. Registering a system generates a new id for the site and individual uuids for each heat pump. The registration process allows for the selection of a monitoring system [as entered by oTherm staff] and requires a reference identifier used by the monitoring service provider (e.g. MAC address or installation id).

Data Exchange between oTherm and MSPs

Porting data from the monitoring service provider (MSP) database to oTherm may be accomplished in a number of ways. While not yet finalized, it is anticipated that the MSP will 'push' data to oTherm at regular time intervals. The object pushed would include (in json format) the uuid of the heat pump equipment, an identifier (e.g. API Key) for the MSP, and a time series of measured values labeled with the MSPs column names and units. oTherm will then check the column names against those expected for the specified monitoring equipment, make necessary conversions for both time zone and units, and store in database.

Data portal for end users

oTherm will provide access to (anonymized) database through simple online forms. The specifications for the user interface will be developed as part of Task 4.

References

PDF files of the references can be obtained at: https://paperpile.com/shared/wl2e7b

DOE, 2019, GeoVision: Harnessing the Heat Beneath Our Feet, U.S. Department of Energy, DOE/EE-1306, 218pp.

OIML R75, 2002, Heat Meters, Part 1: General Requirements, International Organization of Legal Metrology, R75-1 Edition 2002.

SunSpec, 2013, Francis, B., B. Fox, F. Nagy, J. Nunneley, T. Tansey, S. Lapointe, M. Heinze, S. Kerrigan, D. Loflin, M. Herzig, B. McCanlies, J. Child, N. Christophorsen, 2013, Open Solar Performance and Reliability (oSPARC) Implementer's Guide, Version 1.0, SunSpec Alliance, 24pp.