DRAFT – For Review

Metering and Measurement of Thermal Energy

Prepared for: New Hampshire Public Utilities Commission

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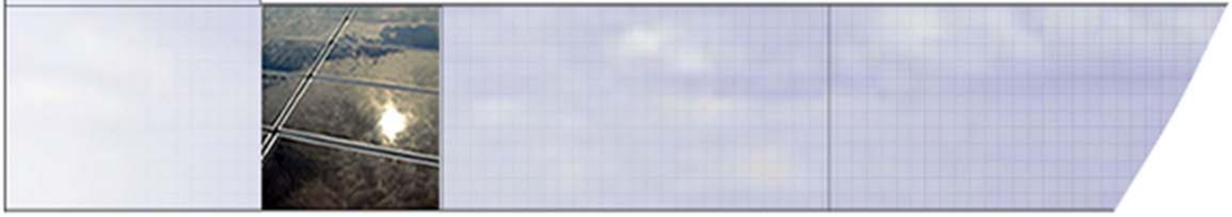

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2.1 SUMMARY OF STATUTE AND PRELIMINARY DRAFT RULE

This section gathers in one place and highlights key provisions of the original New Hampshire law that created the renewable thermal energy subclass of technologies eligible for the state renewable portfolio standard (RPS), including revisions to the law that were enacted before the draft of the revision to the rule was completed, and some of the key elements of the initial preliminary draft of the rule. The focus is on provisions that define the range of qualified technologies and requirements related to thermal metering requirements.

New Hampshire Senate Bill (S.B.) 218 became effective on June 19, 2012. It amended the New Hampshire electric RPS law, RSA 362-F, to create a Class I sub-class for useful thermal renewable energy. The law requires the New Hampshire Public Utilities Commission (Commission) to adopt procedures for the metering, verification, and reporting of useful thermal energy output. The statute defines useful thermal energy as renewable energy delivered from Class 1 sources that can be metered and for which fuel or electricity would otherwise be consumed. From this language and background on how the law developed there is a strong presumption that the legislature wanted actual metering of thermal energy, which guides our recommendations. However, for some technologies, like residential solar water heating, that come in small increments and whose cost can be heavily influenced by the expense of energy metering we also reviewed and offered alternatives to continuous thermal energy metering for the PUC to consider.

The new subclass includes new thermal sources beginning operation after January 1, 2013 and located in New Hampshire. Eligible resources include solar thermal, geothermal, and biomass. The generation technologies need to provide output “in the form of direct heat, steam, hot water, or other thermal form that is used for heating, cooling, humidity control, process use, or other valid thermal end uses” to be eligible. This creates a wide range of technologies that might qualify. Therefore to the extent possible our recommendations are for metering systems and equipment that can be broadly applied to any technology that qualifies, but with an emphasis on those technologies that are most likely to be deployed in New Hampshire and are amenable to continuous metering.

The useful thermal requirement sets annual, incremental targets for thermal renewable energy. The thermal requirement was scheduled to begin in January 2013 but Commission Order No. 25,484 delayed the start of the thermal subclass until 2014 due to technical challenges preventing the timely completion of the rulemaking required to certify facilities for the production of useful thermal energy. Absent the rule and without the delay, electricity providers would have been unable to meet the thermal requirement and would have incurred alternative compliance payments (ACP) because of the limited availability of eligible thermal resources in 2013. As a result of the Order, the RPS was modified by adding the useful thermal obligation for 2013 to compliance year 2014.

Recently some additional modifications have been made to the New Hampshire RPS with Senate Bill (S.B.) 148 becoming effective on July 24, 2013 and House Bill (H.B.) 542 becoming effective on July 27,

2013. These modifications include adjustments to the yearly minimum RPS percentage targets. For the annual minimum useful thermal RPS percentage targets, H.B. 542 and S.B. 148 set the percentage for 2014 at 0.4%, and 0.6% in 2015, 1.3% in 2016, and increases annually by 0.1% from 2017 through 2023, after which it stays constant at 2.0%. The below discussion reflects changes made by S.B. 218, S.B. 148 and H.B. 542 to the New Hampshire RPS related to the thermal provisions.

Facilities using biomass thermal resources must meet nitrogen oxide (NOx) and particulate matter (PM) emissions requirements. For thermal biomass energy technologies that began operation after January 1, 2013, H.B. 542 and S.B 148 made minor editorial changes to the emission provisions. Units between 3 and 30 MMBTU/Hr design gross heat input shall have an average particulate emission rate less than or equal to 0.10 lbs/MMBTU. Units larger than 30 MMBTU/Hr shall have an emissions rate less than or equal to 0.02 lbs/MMBTU. For NOx emissions, units greater than 100 MMBTU/Hr gross heat input shall have a quarterly average NOx emission rate of less than or equal to 0.075 lb/MMBtu.[1] Units less than 100 MMBtu/Hr must implement best management practices.

Under H.B 542 and S.B. 148, there is also a special provision for units that are an upgrade or replacement of an existing unit that primarily fired biomass prior to January 1, 2013. The replacement or upgrade shall be a combined heat and power unit that provides district heating. At least 80% of the tax basis of the unit, excluding property and intangible assets, shall be derived from capital investments directly related to the upgrade or replacement, made on or after January 1, 2013. These refinements in the qualifications for biomass thermal systems limit which technologies/applications are likely to qualify.

For all eligible thermal energy technologies, an independent entity designated by the Commission is required to monitor and verify energy production from thermal sources or the Commission can determine another adequate means to verify production. S.B. 218 appears to have left some room for interpretation on the schedule and nature of such verification. This is an important consideration. The economic impact of monitoring can be very different for large systems (typical of biomass CHP) compared to smaller systems (ground-source heat pumps for light commercial buildings). Depending on what is included in the verification, the level of expertise or knowledge required can vary. CHP has complex energy flows between the power generation and thermal generation components of the system that can be more complicated to verify than a simple biomass boiler. The metering system and the approach required for verification need to be economical and reliable in combination.

S.B. 218 also established an initial price ceiling for alternative compliance payments of $25 per thermal REC for each megawatt-hour (MWh) not met through the acquisition of RECs for the RPS Class I thermal subclass requirement. The alternative compliance payment was used as an estimate of the value of the thermal RECs in our consideration of thermal metering and verification options. Small systems may only produce a few RECs in a year, where a larger system may produce hundreds. The value of the thermal RECs for a small system may not offset the expense of adding metering to systems that usually operate without a meter. Larger systems, which are typically well metered in order to optimize operations and energy production, will probably incur minimal extra costs for metering and verification and so any value derived from thermal RECs will be less eroded by the costs of participating.

In January 2013, the Commission issued for public comment a preliminary draft revision of PUC 2500, *Electric Renewable Portfolio Standard*, which incorporates the provisions of S.B. 218. The preliminary

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[1] The bill contains a typo. It reads 0.075 MMBtu/hr, but should have read 0.075 lbs/MMBtu.

draft rule provides implementation details including modifications to renewable energy certificate (REC) requirements, the RPS compliance schedule for renewable thermal energy sources, and the acquisition of commission-issued certificates. Among the key thermal requirements delineated are criteria for certification and the requirements for monitoring, verification, and reporting of renewable thermal energy sources. The certification of renewable solar thermal, geothermal, biomass, co-firing, and combined heat and power (CHP) systems relies on system performance and configuration information supplied by the applicant to establish a project's qualification. The rule included provisions for monitoring, verification, and reporting of renewable thermal energy sources to comply with the requirements of the statute. Metering equipment specification and accuracy criteria is referenced in this section of the preliminary draft rule. Other key provisions in the monitoring, verification, and reporting section include independent monitoring requirements to verify production. The purpose of this document is to provide more details on the measurement and metering provisions of thermal RECs and serve as the basis for an expanded and more detailed revision to PUC 2500.

2.2 KEY REQUIREMENTS FOR ENERGY MEASUREMENT

This section discusses the key renewable thermal energy provisions of S.B. 218 in more detail.[2] It cites the statutory language and where appropriate the understanding or interpretation of the provisions that are built into the assumptions for our analysis. The statute amends the New Hampshire RPS by defining useful thermal energy as energy transferred to end-use processes where the heat generated is usable, does not include any ancillary heat that is not useful thermal energy, and can displace electricity or any other type of fuel:

> *…renewable energy delivered from class I sources that can be metered and that is delivered in New Hampshire to an end user in the form of direct heat, steam, hot water, or other thermal form that is used for heating, cooling, humidity control, process use, or other valid thermal end use energy requirements and for which fuel or electricity would otherwise be consumed.* (RSA 362-F:2, XV-a)

Measurement of useful thermal energy output is needed in order to calculate renewable energy certificates (RECs) for thermal energy produced in each quarter. Generation of RECs for each unit of useful thermal energy produced is measured on an electric equivalency basis, with each 3.412 million BTUs of thermal energy produced equal to one MWh.

> *A qualified producer of useful thermal energy shall provide for the metering of useful thermal energy produced in order to calculate the quantity of megawatt-hours for which renewable energy certificates are qualified, and to report to the public utilities commission under rules adopted pursuant to RSA 362-F:13. Monitoring, reporting, and calculating the useful thermal energy produced in each quarter shall be expressed in megawatt-hours, where each 3,412,000 BTUs of useful thermal energy is equivalent to one megawatt-hour.* (RSA 362-F:6, V)

The statute requires the Commission to create thermal REC measurement and verification protocols in coordination with the Independent System Operator-New England, which can include the aggregation of sources for fractional or whole RECs by a third-party provider. The statute also requires monitoring and verification of energy production by an independent entity as determined by the Commission or by such other means as the Commission deems adequate.

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[2] The following indented text in italics reflects the modifications to the New Hampshire RPS statute.

> The commission shall establish procedures by which electricity *and useful thermal energy* production not tracked by ISO-New England from customer-sited sources, including behind the meter production, may be included within the certificate program, provided such sources are located in New Hampshire. The procedures may include the aggregation of sources and shall be compatible with procedures of the certificate program administrator, *where possible*. The production shall be monitored and verified by an independent entity designated by the commission, which may include electric distribution companies, *or by such other means as the commission finds adequate in verifying that such production is occurring*. (RSA 362-F:6, II)

3 OVERVIEW OF PUBLIC COMMENTS ON THE PRELIMINARY DRAFT RULE

3.1 SYNOPSIS OF COMMENTARY

The Commission conducted two stakeholders meetings, the first of which was held on August 3, 2012 after the passage of S.B. 218 and a second meeting focusing on the preliminary draft rule was held on January 25, 2013. Public comments were submitted on a wide range of subjects that are summarized in this section, with an emphasis on those that affect the scope or approach to metering.

The Commission received public comments related to solar thermal technologies from: SunDrum Solar, Net Zero Meter, and the International Association of Plumbing and Mechanical Officials (IAPMO). These comments addressed suggested standards for revenue grade meters, temperature sensors, and current transformers; flow meter accuracy specifications; and a preliminary study on the performance monitoring of Massachusetts' Commonwealth Solar Hot Water Program. In addition, the submitted comments included issues regarding the certification requirements for solar thermal systems.

Certification requirements are most relevant to ensuring that solar thermal systems meet quality and code requirements for safety, durability and performance and are generally not essential to the methods prescribed in this report for metering thermal energy. In the proposed methodology below we include a provisional method for residential scale systems where the certification requirement will be an important ingredient.

The biomass-related comments were submitted by the following companies and membership organization: Concord Steam, New England Wood Pellet, and the National Biodiesel Board. These comments and suggestions to the preliminary draft rule were on a wide range of topics, including existing thermal loads, metering and monitoring, alternative testing, the licensing of independent monitors, expanding the definition of Class I thermal subclass sources, the monitoring of renewable energy sources producing useful thermal energy, and estimation approaches for calculating thermal energy output.

Estimation approaches which do not include some form of continuous monitoring are not in keeping with the intent of the statute.

The geothermal comments were provided by the New England Geothermal Professional Association (NEGPA), Water Energy Distributers, and a coalition of geothermal community organizations including Ground Energy Support, WellSpring Geothermal, HeatSpring, NEGPA, Energy Smart Alternatives, and Water Energy Distributors. This group of comments addressed metering approaches for geothermal heat pumps (GHP), including direct, indirect, and aggregated thermal energy transfer measurement methods. In addition, these comments included input on data collection points for system production measurement, reporting of system production data; metering system installation and measurement accuracy; and metering system validation. The comments also noted points of clarification and provided suggested rule language for the following sections: application requirements; certification of geothermal systems; monitoring, verification, and reporting; and independent monitors.

The comments will be carefully considered and to the extent they are consistent with the meaning and intent of the statute incorporated into our recommendations. When that section is complete a clear response will be added here.

In addition, a set of general comments were submitted by Net Zero Meter, Public Service of New Hampshire, the New England Geothermal Professional Association, and New England Wood Pellet. Among the subjects they provided input on included metering, monitoring, and communication, and referencing ANSI standards for meters and current transformers. These comments also included a recommendation about documenting BTU accuracies as an approach to meeting the thermal production verification requirement.

3.2 DISCUSSION OF KEY ISSUES FOR THERMAL ENERGY MEASUREMENT

Metering equipment specification standards were among the areas highlighted in the submitted public comments. The IEC 751 equipment specification standard for temperature sensors was suggested. This comment narrowly addresses one type of temperature sensor and related standards and will be considered, although the broader OIML standards mentioned in other comments and programs cover a broader scope that includes flow meters for systems with liquid as the heat transfer mechanism. Our recommendation is to specifically adopt the OIML standards and equivalent U.S. Standards when they are adopted. This avoids a piecemeal approach to setting standards for heat meters.

A ±0.5% or better specification was suggested for flow meter accuracy.

In the methodology proposed in this report we are recommending that the OIML recommendation for heat meters and its U.S. implementation in standards, currently under development by ASTM, be the standard for accuracy. The current OIML standard prescribes a dynamic maximum permissible error band based on system operating conditions.

A comment was also submitted on the topic of product certification of eligible solar thermal systems. Comments from IAPMO proposed certification of solar thermal systems by a body accredited by the American National Standards Institute (ANSI) rather than through a single certification organization such as the Solar Rating and Certification Corporation (SRCC). IAPMO notes that there is now a competitive market for solar thermal product certification services, which was previously largely being served by SRCC, and that state incentive programs are recognizing ANSI-accredited laboratories that certify products for participation in state programs; so states are moving toward referencing the standards setting body, ANSI, in program requirements rather than only the certification organization, SRCC. These states include Arizona, California, Louisiana, and Nevada. For the solar water heating Federal tax credit, the Federal government recognizes product certification by SRCC or a comparable organization endorsed by the state government where the system is installed.

Certification requirements are most relevant to ensuring that solar thermal systems meet quality and code requirements for safety, durability and performance and are generally not essential to the methods prescribed in this report for metering thermal energy. In the proposed methodology below we include a provisional method for residential scale systems where the certification requirement will be an important ingredient. Both SRCC (in combination with the ICC, International Code Council) and IAPMO are trying to advance new solar thermal standards for collectors and systems. If the PUC accepts our proposed provisional methods for residential size then both groups' approaches will be incorporated.

For geothermal heat pump (GHP) systems, the submitted comments recommended metering GHP systems using a measurement approach similar to the methods used for the metering solar thermal energy output. One of the submitted comments outlines approaches for direct, indirect, and aggregated thermal energy transfer measurement methods.

One of the comments recommended only calculating GHP contributions to heating, our analysis includes an approach to also capturing the cooling contribution of GHPs. The standards for heat metering equipment will be the same as for solar thermal systems, based on the OIML R75 recommendations to start, and replaced by the ASTM standard that is currently in development. The ASTM standard is expected to be harmonized with EN1434, which should make most existing equipment that meets CEN standards eligible. The proposed implementation method for metering useful energy output from geothermal liquid phase ground loop systems including antifreeze protected systems consists of four steps:

- *System Commissioning Performance Test based on methods adapted from ISO standard 13256 - to determine for the owner that the system performs as certified or warranted, to determine the heat meter is calibrated and working as designed and to measure compressor and ground loop pump energy consumption coefficients that will be used to calculate net useful energy output;*
- *System Test Report - The system vendor/commissioner will prepare a one page report for the results of performance test in a standardized format;*
- *Quarterly Heat Generation Reporting – The total eligible useful heat production of the period, a narrative describing meter calibrations performed and any issues with meter operation or recording, and supporting spreadsheet calculations for determining net useful thermal energy generation for the period;*
- *Annual System Calibration and Performance Test – Each year the performance test will be repeated and an estimate of yearly production based on test results will be compared to the reported heat generation for that period.*

In regard to a thermal energy output estimation approach, a submitted comment suggests an estimation approach for calculating biomass thermal energy output based on the use of conservative default boiler seasonal efficiency values for biodiesel, pellet, chip-, and logwood-fired systems. This approach entails the use of liquid fuel metering of biodiesel-fired systems as the primary input measurement plus fuel purchase/inventory records as a method of confirming the input measurement. For this method, the comments note that annual stack loss efficiency tests would also be needed within a range of 50-100 % load conditions. To then determine the total qualified thermal energy output, thermal efficiency is multiplied by total volume of fuel used, with the standard energy content of fuels in BTU units converted to kilowatt hours to provide data in units consistent with the New Hampshire statute.

Estimation approaches which do not include some form of continuous monitoring are not in keeping with the intent of the statute.

4 ASSESSMENT OF CURRENT METHODS FOR MEASUREMENT OF THERMAL ENERGY APPLICABLE TO THE RPS RULE

4.1 CURRENT METHODS AND STANDARDS FOR MEASURING USEFUL THERMAL ENERGY OUTPUT

The field for the development of standards for metering heat and determining system performance has been very active recently and as incentives for alternative thermal energy technologies move from one time installation incentives to ongoing performance based incentives the demand for accurate metering will increase. A summary of the state of the art of technology and standards for metering thermal energy is provided here.

Referencing standards and appropriate certification to standards is desirable for ensuring acceptable levels of accuracy and performance in heat metering equipment. Standards and appropriate certifications also protect both consumers and installers from poor equipment and make product features and performance easier to compare. This section will cover standards and equipment certification issues for thermal measurement in liquid heat transfer systems, steam systems, and direct air heat transfer.

4.1.1 THERMAL MEASUREMENT STANDARDS FOR LIQUID HEAT TRANSFER SYSTEMS

Standards and certifications take time to adjust to innovative new technologies, which can slow their introduction to the market. Current thermal metering instrumentation for liquid heat transfer loops, the main topic of this section, is well-established with applicable standards for performance, testing and installation. Many metering systems also offer optional equipment for transmitting the data to a server or website. New technologies such as the Ohm metering system have the potential for lowering costs but the existing standards for thermal metering do not include them. Relevant standards for thermal measurement technologies are in flux, so there is a challenge in keeping New Hampshire's methods and approach up to date as standards change or new standards are developed. Standards organizations are typically organized in a hierarchy, with international organizations like the International Organization for Standardization (ISO) or the International Organization of Legal Metrology (OIML) acting to build an international consensus on a standard (ISO) or a recommended standard (OIML) that participating national standards organizations then adapt and promulgate within their host nations or regions – the European Committee for Standardization (CEN) and its EN series of standards in Europe, American Society for Testing and Materials (ASTM), American Society of Heating and Refrigeration Engineers (ASHRAE), and other institutions in the United States. The following are the major international, European, and in-progress U.S. standards for heat meters in systems involving liquid heat transfer:

- The International Organization of Legal Metrology (OIML) R75 series of recommendations were the basis European Standard EN1434 Part 1 and are the most relevant for thermal metering in solar collectors using water or another heat transfer fluid. The series on Heat Meters includes:

  - R75-1 which specifies general requirements and scope of application to instruments intended for measuring the heat which, in a heat exchange circuit, is given up by a heat conveying liquid.
  - R75-2 specifies type approval tests and initial verification tests
  - R75-3 specifies the test report format
- EN1434-1 to EN1434-7 incorporates and expands on the OIML R75 series, as adapted by the European Committee for Standardization (CEN) Technical Committee 176 (CEN TC 176 into European standards for heat meters.
  - Part 1. General Requirements
  - Part 2. Constructional Requirements
  - Part 3. Data exchange and interfaces
  - Part 4. Pattern approval tests
  - Part 5. Initial verification tests
  - Part 6. Installation, commissioning, operational monitoring and maintenance.
- The U.S. does not have a heat meter standard. The American Society of Testing and Materials (ASTM) International E44.5 committee is considering both the OIML R75 series and the EN1434 in deliberations to create a U.S. heat meter standard. Their schedule is aimed at balloting for a final standard at the end of 2013. A draft of their standard is available and is included in our recommendations for thermal measurements.

ISO 9459-2: "Solar Heating - Domestic water heating, systems - Part 2: Outdoor test methods for system performance characterization and yearly performance prediction of solar-only systems" sets standards for outdoor testing of solar water heating systems, and is a precursor to EN 12975-2: "Thermal solar systems and components, Part 2: Test Methods." used by the European Union testing and certification program. The practical methods for outdoor testing in this standard are a useful guide to setting up the metering and measurement of systems in New Hampshire both as part of commissioning and the proper application of thermal and flow meters and interpreting their results to predict/measure performance. These test methods are valuable as system commissioning templates which measure and verify key performance factors for measuring net useful energy output.

In addition to the standards that apply to the thermal measurement instruments, solar thermal systems in the U.S. are typically tested and certified to standards that ensure safety, durability, and performance. In terms of measuring and verifying output from solar thermal systems the performance element of testing and certification is important if New Hampshire chooses to allow small size systems to use a combination of commissioning, simplified metering and performance estimates to calculate thermal output with periodic inspections required. These are the main standards and certifications considerations involved in using estimates rather than direct metering for solar thermal systems:

- Standardized saving calculations provide an estimate of solar energy production based on accounting for the backup water heater and parasitic losses as long as the comparison system uses the same backup. For most packaged systems these can be taken directly from the Solar Rating and Certification Corporation’s (SRCC’s) website where test data on collectors and systems certified by SRCC are entered in an estimation tool that can derive savings in kBTU and kWh for a typical system in Concord New Hampshire. The assumptions are very basic but for small size systems the variation in accuracy is unlikely to have a significant impact on the overall program. More detailed calculators can be developed (i.e., CSI-Thermal) that allow more variables, including more detailed solar fraction calculations, collector orientations, etc.

- If solar thermal systems are allowed to estimate energy production in lieu of metering, collectors and systems must be tested to verify the performance of specific products. Test results can then be used to estimate their energy production using standard assumptions on weather, installation, and backup energy. This is usually accomplished through product testing and certification to a standard. There is growing competition in this area of standards and certification:
    - OG-100 (collectors) OG300 (systems) and OG600 (solar concentrating collectors) are the most established and widely used standards for testing solar thermal collector and system performance, safety and durability in the United States. They are promulgated by the Solar Ratings and Certification Corporation (SRCC), which has approved 18 labs in Europe and North America to test to the standards. Once tested, systems are then eligible for certification by SRCC. Until recently SRCC had a substantial backlog of collectors and systems awaiting test and certification, but the backlog has been greatly reduced and with the expansion of test labs there is likely adequate capacity to keep up with applications.
    - SRCC and the International Code Council (ICC) have filed a Project Initiation Notification System (PINS) notice with the American National Standards Institute (ANSI) to form a Standards Development Committee to develop *ICC90/SRCC 300, Minimum Standards for Solar Thermal Collectors* and *ICC901/SRCC100 Minimum Standards for Solar Thermal Collectors.* This commits ICC and SRCC to the policies and procedures for consensus development of American national standards. The new standards will be based on the current OG100 and OG300 standards.
    - The International Association of Plumbing and Mechanical Officials (IAPMO) also certifies solar collectors and starting in 2011 began certifying residential size systems. IAPMO certifies to all SRCC standards as well as their own Uniform Solar Energy Code, Uniform Plumbing Code, and Uniform Mechanical Code. IAPMO is an ANSI-accredited certification body as well as an ANSI-credited standards developer. They have been recognized along with SRCC as a certification body to the OG300 standard in the states of Arizona, California, Louisiana, and Nevada and are also eligible under the wording of the internal revenue code provisions for the residential and commercial energy efficient property investment tax credits.
    - IAPMO has submitted a PINS request with ANSI, and is using the American National Standards Institute policies and procedures for consensus development of American national standards to develop IAPMO S1001.1 Design and Installation of Solar Water Heating Systems, based on the Florida Solar Energy Center (FSEC) Standard FSEC 104.
- For geothermal heat pump systems the most relevant standard for performance measurement is International Organization for Standardization (ISO) 13256 Water-source heat pumps – Testing and rating for performance, Part 1: Water-to-air and brine-to-air heat pumps codified

into a U.S. standard as ANSI/ARI/ASHRAE ISO Standard 13256-1, last updated on 12/5/2012. Part 2 is specific to water-to-water and brine-to-water heat pumps.

- ISO is an organization dedicated to developing voluntary international standards. Its voluntary standards are widely recognized and used – over 19,500 international standards have been produced by ISO since its inception in 1947.
- ANSI, ARI and AHSRAE are American standards organizations. In contrast to ISO, their standards are generally adopted by U.S. industry and government and incorporated into laws, rules and regulations. In effect ANSI, ARI and ASHRAE adopting the IOS 13256 standard makes it an applicable American standard that suits New Hampshire's needs.
- The standard applies to testing of factory-made residential, commercial and industrial geothermal heat pump systems that are electrically driven, mechanical compression type systems that are the most common. It does not apply to customized field-built systems, nor is it valid for individual assemblies/components of heat pumps for separate use.
- It is valid for systems providing heating and cooling.

4.1.2 METERING STANDARDS RELATED TO STEAM

4.1.3 METERING STANDARDS RELATED TO DIRECT AIR HEATING

4.2 STATE RPS APPROACHES TO DETERMINING USEFUL THERMAL ENERGY OUTPUT

Solar water heating is allowed by Washington, D.C. and 13 state RPS', including Maryland, Vermont, New Hampshire, Pennsylvania, New York, Indiana, Wisconsin, North Carolina, Texas, Colorado, Hawaii, Nevada, and Arizona. Solar space heat and solar thermal process heat are allowed by 7 jurisdictions.[3] Additionally, biomass heating is also eligible under the RPS in Wisconsin and Arizona. Combined heat and power (CHP), cogeneration, or energy recovery is eligible in 13 states,[4] though some states place restrictions on what types are eligible (DSIRE & NREL, 2012).

The below section is an overview of some state RPS programs that include renewable thermal energy resources to meet RPS targets. Among these states, the approach to the inclusion of thermal resources varies in terms of eligibility of sources, incentive/rebate-based program design, and REC generation. For instance, like New Hampshire, Arizona, Massachusetts, and Washington, D.C. allow renewable thermal energy to displace all fossil fuels. A few have thermal output metering provisions written into their RPS rules or guidance documents, such as Maryland, Washington, D.C., and New York. Among these jurisdictions, most do not address detailed aspects of metering instrumentation and accuracy. The California Solar Initiative – Thermal Program, however, has developed specifications for thermal meters and testing, including an approved list of metering equipment.

New Hampshire can learn from the successes and problems encountered by other states, and their approach to resolving issues. Several states have attempted to require thermal metering for large

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[3] Both sources are allowed in Arizona, Washington, D.C., Hawaii, Nevada, North Carolina, Pennsylvania, and Wisconsin.

[4] Arizona, Connecticut, Hawaii, Maine, Michigan, Nevada, New York, North Carolina, Ohio, Pennsylvania, Washington, West Virginia, and Wisconsin

system allowing small systems to opt for estimation protocols. California has the most detailed specifications for metering of systems with capacity 30kW$_{th}$ or greater.

Maryland

Maryland's solar carve out allows solar water heating systems commissioned on or after June 1, 2011 to qualify as eligible resources, effective January 1, 2012. In order to qualify for the RPS solar water heating systems must:

- be commissioned on or after June 1, 2011;
- not be used solely to heat a pool or a hot tub; and
- use SRCC OG-100 certified equipment.

Residential solar water heating systems may be equipped with a meter that satisfies OIML requirements, or may use an SRCC OG-300 annual energy estimate for the purposes of solar renewable energy certificate (SREC) creation. Residential solar water heating systems are limited to producing five SRECs annually. Non-residential solar water heating systems must be equipped with a meter that meets the standards of the OIML. Maryland also allows solar water heating energy production measurements for some systems to be estimated under a certification system other than SRCC OG-300, which is subject to Public Service Commission approval. (MD PSC & DSIRE 2013).

In 2012, the Maryland RPS began allowing geothermal heating and cooling systems commissioned on or after January 1, 2013 that meet certain standards to qualify as a Tier I resource. Also, in May 2012 Maryland began allowing thermal energy associated with biomass systems that primarily use animal waste (possibly supplemented by other biomass resources) to qualify as Tier I resources, effective January 1, 2013.

Maryland is less specific about metering requirements and verification than we recommend. They have allowed estimation for solar thermal systems, which is included as an option for New Hampshire to consider. Their accommodation of systems certified to other than OG-300 standards is a useful example.

Washington, D.C.

Washington, D.C. offers financial incentives for solar thermal systems through its Renewable Energy Incentives Program (REIP). In April 2012, solar thermal systems became eligible for the REIP program. Incentives cover solar thermal systems that are used to offset the use of electricity or gas for radiant/space and/or water heating. All solar thermal systems are allowed to use SRCC methods to estimate performance. For residential systems, collectors are required to be rated and certified OG-100 by the SRCC, and if metered the actual energy output is to be determined by an onsite energy meter that meets performance standards established by OIML. For non-residential systems 10,000 kWh (341.2 Therms) per year or more, collectors must be rated and certified OG-100 by SRCC, and if metered the actual energy output is to be determined by an onsite energy meter that meets performance standards established by OIML. For non-residential systems 10,000 kWh (341.2 Therms) per year or less, systems are to be rated and certified by SRCC, and the energy output should be determined by one of the following:

- The SRCC OG-300 annual systems performance rating protocol; or
- The SRCC OG-100 solar collector rating protocol; or
- An onsite energy meter that measures the actual energy output and meets performance standards established by OIML. (DC REIP Guide, 2012)

Washington DC's reliance on OIML was based on the only standard that could be referenced for U.S. purposes (EN standards are restricted to the European Union). New Hampshire has the opportunity to include the equivalent ASTM standard that is under development for heat metering, which will be the implementation of the OIML R75 series in the United States.

Massachusetts

In August 2012, Massachusetts passed legislation requiring the state to study adding technologies that generate "useful thermal energy" to the list of eligible technologies under the alternative energy portfolio standard (APS), which requires meeting 5% of Massachusetts' electric load with "alternative energy" by 2020. In the interim, the Massachusetts Clean Energy Center (MassCEC) launched the Commonwealth Solar Hot Water Pilot Program to serve residential, commercial, and low-income housing sectors. Rebates are offered under the residential pilot program for solar hot water construction projects at single-family and multi-family (up to 4 units) residences. The systems may offset any type of fuel. Solar water heating systems for domestic water heating and space heating are eligible. Pool heaters do not qualify for the rebate; however, space heating and combined systems do qualify. Collectors must be OG-100 certified and systems OG-300 certified. Residents have the option of participating in a metering performance monitoring program through which they can receive an additional $1,500 to cover the costs of a meter installation, and an additional $200 if the system includes parts that are manufactured in Massachusetts. The metering program will be used to assist in the design of the follow-up program to the pilot program (DSIRE & MA Clean Energy Center).

The structure of the pilot program and the results of metering provide some useful information on how New Hampshire could structure a monitoring program, and when complete the results should provide useful data on what to expect from renewable thermal systems in New Hampshire.

North Carolina

In North Carolina, useful thermal energy must be either metered or, if that is not practical, calculated using an industry-accepted means, which is subject to audit unless the meter is supplied by and read by an electric power supplier. Eligible solar thermal resources in the North Carolina RPS include solar hot water, solar absorption cooling, solar dehumidification, solar thermally driven refrigeration, and solar industrial process heat. CHP facilities that use biomass and CHP facilities that use poultry waste are also eligible sources. RECs are earned based on 1 MWh for every 3,412,000 BTU of useful thermal energy produced (04 North Carolina Administrative Code 11 R08-64, et seq.). The North Carolina Renewable Energy Tracking system provides a registry and tracking system for renewable thermal RECs.

North Carolina's program covers the widest range of solar technologies and is a useful precedent for New Hampshire to use in developing its CHP thermal renewable resources. NC-RETS, run by APX, provides some useful insights into registering and tracking renewable thermal RECs.

Arizona

The Arizona RPS allows the participation of the following thermal renewable energy technologies: solar water heat; solar space heat; solar space cooling; solar thermal process heat; commercial solar pool heating; solar heating, ventilation and air-conditioning (HVAC); and geothermal heating (but not cooling). Biomass thermal systems, and the heat and electrical output of renewably fueled combined heat-and-power systems are also allowed under the RPS. Arizona allows renewable thermal use to displace any fossil fuel source (DSIRE & Meister).

California

The California Solar Initiative –Thermal Program offers financial incentives for natural gas-, electric-, and propane-displacing solar thermal systems in all investor-owned utility territories. Under the program, all systems with the capacity of over 30 kW_{th} must have metering and monitoring equipment to measure system performance (the quantity of energy generated or displaced by the system). Residential systems must be certified to SRCC OG-300 by either SRCC or International Association of Plumbing and Mechanical Officials (IAPMO). Solar collectors used in eligible commercial systems must be certified to SRCC OG-100 by either SRCC or IAPMO. Also, only non-residential solar pool heaters are eligible. In February 2013, the California Public Utilities Commission modified the program to allow other solar thermal technologies to qualify for incentives. Commercial combined solar water heating and solar space heating, solar process heat, and solar cooling will all qualify for performance based incentives through this program (CPUC & DSIRE). The program allows estimation of thermal renewable energy from small solar thermal systems, but for larger systems provides an approved list of thermal metering packages, and sets requirements for both thermal and flow meter accuracy.

California has one of the largest solar thermal markets in the U.S., so their requirements were carefully considered in our recommendations. To the extent New Hampshire’s requirements are compatible with California, more manufacturers and developers will have solar thermal products ready to install, leading to more competition. California’s requirements for metering accuracy and the meters on their approved list were examined when developing our recommendations.

New York

The New York State Energy Research and Development Authority (NYSERDA) provides incentives for the installation of new solar thermal systems for the production of hot water to displace electrically heated hot water. Incentives are based on displaced electrical usage based upon SRCC OG-300 estimates of system production and/or standard industry software such as RETScreen, or SolarPathfinder thermal program. For solar panel manufacturers who have SRCC OG-100 panel ratings and have applied for a SRCC OG-300 system rating but have not yet received a rating, an estimate based on the panel’s SRCC OG-100 rating and along with calculations from RETscreen, Solar Pathfinder Thermal or other approved method may be provided. In such cases, a meter must be installed on the system and the amount of energy produced in kilowatt hours must be measured every three months for the first year and reported to NYSERDA (NYSERDA Solar Thermal Program Manual). New York has done extensive work on biomass energy measurement and verification, much of it prepared by ANTARES Group that will provide a foundation for New Hampshire’s rules.

Wisconsin

The Wisconsin RPS was expanded in 2010 to include renewable thermal energy sources that displace electricity. Eligible renewable thermal sources/technologies include: solar water heaters; ground source heat pumps; and sources that generate thermal output from biomass, biogas, synthetic gas, densified fuel pellets, or fuel produced by pyrolysis of organic and or waste material (WI Public Service Commission & DSIRE).

For residential SWH systems, SRCC OG-300 is required for the statewide Focus on Energy (FOE) incentive program, and the savings are based on SRCC savings estimates for Madison, Wisconsin, only, regardless of where the system is located. There is no direct requirement for metering or monitoring, but FOE does reserve the right to obtain utility records in order to track the energy impacts of an installation. Also, FOE incentives now require an energy efficiency upgrade to the dwelling unit to qualify for the SWH incentive. For commercial systems, the incentives are based on periodic RFPs for projects.

Renewable funding is already depleted for 2013. In general, all savings have to be metered to be eligible for the commercial incentives, including SWH. The legislation (PSC 118.055 and PSC 118.09) allows utilities to create RECs and Renewable Resource Credits (RRCs) based on "non-electric facilities," including solar water heaters. In practice this may not be occurring, but there may be some large SWH systems in the state that are creating RECs (USH20 communication July 2013).

State Approaches to Solar Thermal Energy Measurement

For purposes of REC calculation, currently, two jurisdictions, Maryland and Washington, D.C., have established estimation and metering criteria for the solar thermal energy output of SWH systems. They follow an approach in which equipment thermal output is calculated by using either the annual energy performance estimate provided by SRCC, based on the certification of the equipment, or by converting BTUs to kWh equivalents from a BTU meter.

The Maryland RPS rules outline these provisions in its application requirements for qualifying generators (Code of Maryland Regulations (COMAR) 20.61.02.01). For residential SWH systems, Maryland allows an annual energy estimate provided by SRCC OG- 300 Water Heating System Rating; or the SRCC OG 100 solar collector rating with a meter that complies with OIML requirements and which measures the energy savings of a single tank system collected on the solar loop of the system. The latter provides for the most accurate measurement of solar contribution to the DHW system, avoiding supplementing the measurement with the (non-solar) fossil fuel backup. Non-residential or commercial systems are required to use the SRCC OG 100 solar collector rating with a meter that meets the OIML requirements. Both residential and non-residential systems must use only glazed liquid-type flat-plate or tubular solar collectors. The Maryland rules do not further elaborate on metering equipment accuracy or other metering specifications.

Similarly under the Washington, D.C. RPS rules, smaller systems have the option of estimating thermal output in lieu of direct metering. Output for residential systems can be based on the SRCC OG-300 or OG-100 rating estimate or a meter that meets OIML requirements. For non-residential systems the rules are based on two system output levels. For non-residential systems displacing 10,000 kWh per year or more, output must be metered per OIML requirements and the collectors used must be SRCC OG-100 certified. The output for non-residential systems displacing 10,000 kWh per year or less can be based on the applicable SRCC rating protocol (OG-100 or OG-300) or an OIML compliant meter. Also, both residential and non-residential systems must use only glazed liquid-type flat-plate or tubular solar collectors. In addition, all system components (collectors, controls, sensors, piping, pipe insulation, valves, tanks, heat exchangers, pumps, plumbing,) must be new and must not have been previously placed in service in any other location or for any other application. Rebuilt, refurbished, or relocated equipment are not eligible to receive incentives.

Also for purposes of REC generation and tracking, the Washington, D.C. RPS rules allow estimated thermal output for which the District of Columbia Public Service Commission will provide PJM Environmental Information Service GATS (PJM-EIS GATS) with the output in kilowatt-hour savings, based on the SRCC's estimated annual system performance of OG-300 certified systems. Alternatively, if the solar thermal system is metered with a OIML compliant meter, then the solar thermal energy produced by the system will be credited with 1 kWh of electricity generated for each 3,412 BTUs produced by the solar thermal energy system.

The California Solar Initiative – Thermal Program offers useful examples of specification criteria although its overall design elements differ from the New Hampshire renewable thermal energy RPS carve out. Their guidance on thermal metering provides useful examples that New Hampshire can consider in its metering requirements. The CSI – Thermal Program stipulates required metering equipment, equipment accuracy standards, equipment location, and equipment communication requirements. While the program does not require direct metering for small single-family residential heating systems, systems over 30 kWth have minimum metering requirements. They must have metering and monitoring equipment that measures system performance (the quantity of energy generated or displaced by the system). Required metering equipment consists of a BTU meter (flow meter, temperature sensor pair, and a calculator). The CSI Thermal Program's accuracy standards for metering equipment are as follows:

- Flow meter must have a maximum permissible error ±2% at full flow.
- Temperature sensors must have a maximum permissible error of ± 1° C within the range of temperatures being monitored (e.g. in the case of collector loop monitoring the range would be the minimum collector supply temperature to the maximum collector return temperature).
- For metering that does not include a flow meter and temperature sensor pair, the manufacturer must demonstrate that the accuracy of the total BTU calculation is within ±15%.

The CSI program also maintains a publicly available approved metering equipment list at www.csithermal.com/meters. Metering equipment is added to the approved list based on CSI review of manufacturer submitted equipment accuracy specifications.

The CSI - Thermal Program also requires performance monitoring. For this, the equipment installation location is specified as needing to be on either the collector loop or the potable water side of the SWH system. Also for performance monitoring, the program has communication requirements. These requirements specify that for a period of five years from the start of operation, the system owner must have the means to determine if the system is operating. At a minimum, the performance monitoring equipment must provide the quantity of solar energy delivered to the system owner.

5 BASIC PRINCIPLES FOR MEASUREMENT OF THERMAL ENERGY APPLICABLE TO THE NEW HAMPSHIRE RPS RULE

5.1 BASIC PRINCIPALS FOR DETERMINING USEFUL THERMAL ENERGY OUTPUT

The general principles for determining useful thermal energy output for RPS eligible resources are set forth in this section.

5.1.1 ELIGIBLE END USES AND SYSTEMS THAT CAN BE METERED

For the New Hampshire RPS, Useful Thermal Energy is defined as the useful energy delivered to the end use (in the case of cooling it is the reverse – heat and moisture removed or extracted from air). Eligible end uses include domestic water heating, space heating and cooling, and process hot water or steam production. The statute language is not exclusive with regard to technology or end uses but some systems will be difficult to include at the onset of the program due to challenges in metering the heat output accurately. These include residential wood stoves, low temperature solar pool/spa heaters, and passive solar heating systems (full list is provided in section 5.2).

5.1.2 ENERGY DELIVERY POINT

For purposes of the RPS useful energy delivery should be determined at the delivery point to the distribution system for the building or process heating/cooling system. This delivery point is well defined for every thermal energy system:

- Hot water systems – the exit from the potable hot water tank or liquid phase hydronic space heating or process hot water storage tanks;
- Forced air space heating and cooling – the exit of the air handler where the heat transfer coil is located;
- Process steam – the inlet to the main steam header prior to distribution for multiple end uses the inlet to the steam header for a single process.

This point in the energy system is comparable to the point at which metering for power generators is performed – i.e. at the connection with the transmission and distribution system. It also avoids the very complex metering and accounting required for measuring thermal delivery/removal at the point of use.

5.1.3 METERING AND MEASUREMENT DESIGN

For every renewable thermal energy generation system the critical conversion step is the thermal energy generation step. Continuous metering of this subsystem accurately is central to any methodology that accounts for the renewable portion of useful energy provided to all end uses served by the facility energy system. The continuous energy metering protocols will be applied to the thermal generation subsystem of each system – the energy collector loop for solar and geothermal systems and the steam or hot water generation systems for biomass. This control volume around heat generation is the most crucial and captures the most variable step in the energy conversion process. From that point the end use energy delivered can be calculated with precision based on energy storage loss and operating energy factors for the system as built. Those conversion factors will be measured and established for every system at its commissioning and should be recalibrated annually.

5.1.4 NET ENERGY OUTPUT

Finally, thermal output typically measured in BTU’s in the U. S. must be converted to SI electric equivalent (MWh). Converting non-electric thermal output into a measure equivalent to MWh is done using a direct conversion factor of 3,412,000 British thermal units (BTUs) to 1 MWh. Similarly, non-renewable operating energy inputs deducted from the gross renewable energy thermal generation will be converted from measured units of KWh to BTUs using the equivalent direct conversion factor of 3412 BTU to each 1 kWh electrical energy consumed to operate the system. This treatment is equivalent to the treatment of power plant electric power parasitic use in determining net plant electric output to the grid.

The basic equation used in all methods is:

Useful Thermal Energy Output = Renewable Thermal Energy Generated – Thermal Energy Storage Losses – Operating Energy Inputs (thermal equivalent). Distribution operating energy and losses are specifically not included.

5.2 DIFFERENCES IN APPLICATION TO CLASS I RENEWABLE ENERGY RESOURCES

Solar and Geothermal Applications

Geothermal Heat Pumps and Solar Thermal Systems have in common the use of a collector loop to accumulate the diffuse energy available in solar insolation directly via solar collectors and stored in the ground or ground/surface water via a system of collector pipes. The key subsystem for heat generation or extraction is the collector system. For these systems comparable techniques will be used to measure renewable heat generation. From that point on the factors used to calculate net useful thermal energy at the delivery point differ. Exhibits 1 and 2 illustrate the control volume boundary for heat measurement in two very conceptual system schematics.

Exhibit 1: Solar Thermal

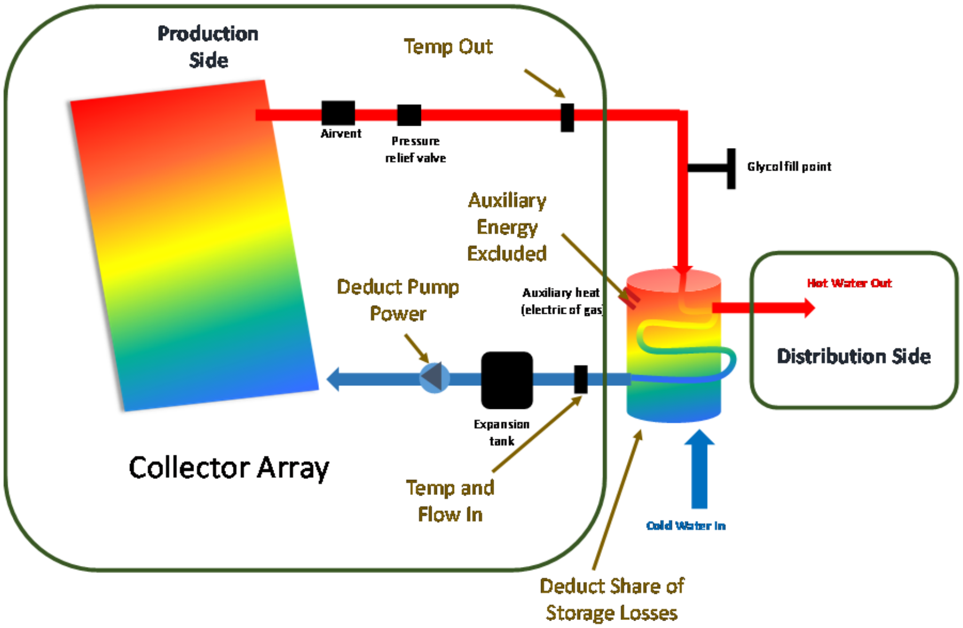
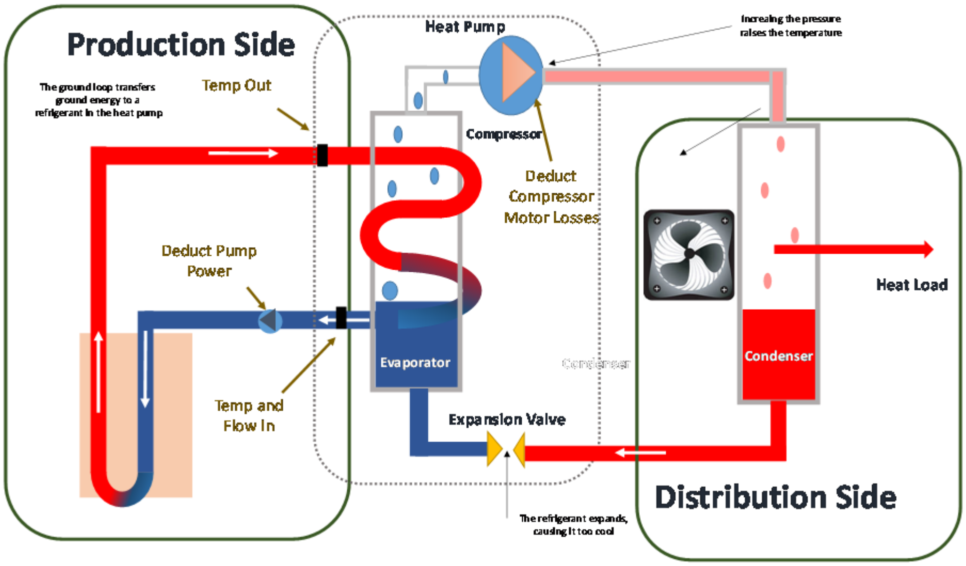


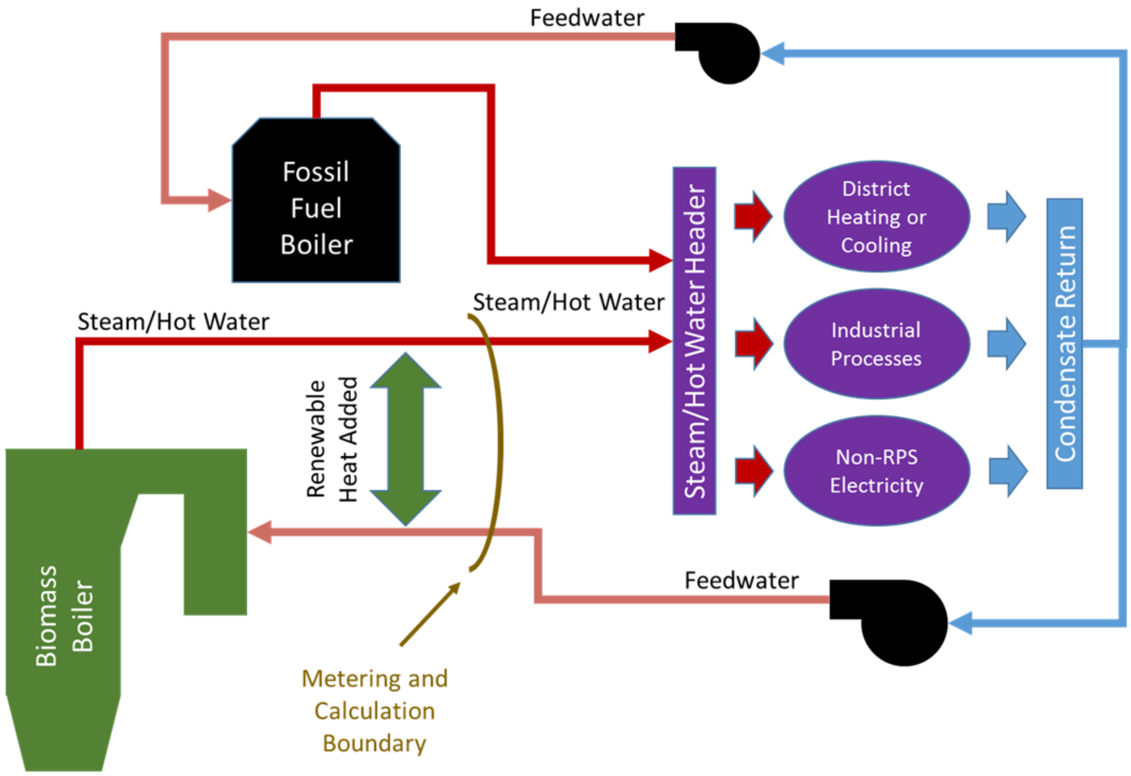
Exhibit 2: Ground Source Heat Pump (Heating Mode)



Biomass Applications

Most biomass systems are quite different in that the solar energy is incorporated into the biomass fuel via photosynthesis in the field or forest and the biomass is harvested and delivered to the plant as a purchased fuel. The appropriate and practical boundary for the measurement of net useful heat input is the boiler and emissions control equipment up to the main steam header. In the biomass systems auxiliary energy use is typically little or none. In this case the control volume for heat generation includes the delivery point and metering and net heat calculations applied without having to factor in downstream energy storage losses or auxiliary energy use. Operating energy will be accounted for in the net energy delivery calculation.

Exhibit 3: Combined Heat and Power



BIOMASS BASELINE THERMAL METERING CONCEPT

Exceptions

The other differences that need to be taken into account in applying the general principles for thermal metering are systems which are now well suited to continuous thermal energy metering. These cases are described below and the methods presented in the subsequent sections are not directly applicable without adjustment.

Residential wood stoves: these systems are popular and have improved efficiency over time but are not easily metered since they exchange heat with the surrounding indoor air and space directly with no simple way to measure energy flows.

Passive solar heating systems: like wood stoves, heat is transferred directly to the surrounding indoor air and space with no easy means of measuring energy flows.

Small-scale solar hot water systems: The California Solar Initiative defines small scale systems as systems with nominal capacity less than 30kW thermal output. For these systems all of the same principals for heat measurement are applicable but the cost of continuous metering would deeply discount or erase the value of the RECs generated by these systems. However, there has been a long established and successful effort to test and certify the performance of these systems such that an alternative metering approach should be considered at least on a provisional basis to allow these systems to be eligible to earn RECs for the energy produced. There is a realistic expectation that the net useful energy determined by these methods will have good accuracy.

High temperature solar and geothermal steam generation systems: The solar and geothermal renewable resources in New Hampshire to support high temperature thermal systems are very limited. If such a system is proposed the principles stated in this report are generally applicable but details of implementation would have to be developed for the application.

6 RESIDENTIAL AND COMMERCIAL SOLAR THERMAL SYSTEMS

6.1 METERING TECHNOLOGY AND THERMAL OUTPUT CALCULATIONS

The method prescribed for solar thermal systems consist of two distinct parts:

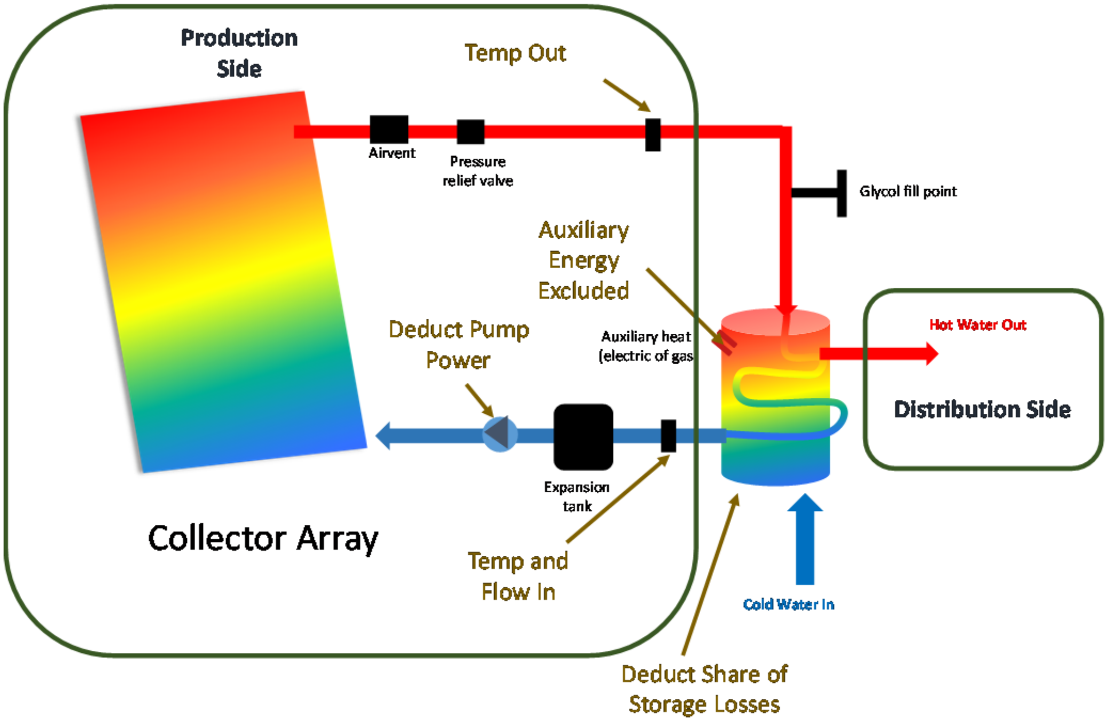
1. Continuous metering of thermal energy generated by the solar collector loop
2. On site measurement of operating pump power inputs and the determination of the thermal storage loss factor(s) and to enable calculation of the net useful thermal energy produced by the system

U.S. Customary and SI units of measure for the equations in this section will both be provided in Appendix XX summarizing all computations prescribed in this report.

6.1.1 CONTINUOUS HEAT METERING FOR LIQUID PHASE HYDRONIC SOLAR THERMAL SYSTEMS

This category encompasses water-based systems with or without antifreeze. The recommended control volume for continuous metering for solar thermal systems is the collector loop.

Exhibit 4: Solar Thermal



Continuous metering requirements for non-concentrating solar collector loops are straightforward. Systems operate at fluid temperatures less than 300 degrees F and fluid pressures typically between 50 and 75 psi. Packaged and combination heat meters (comprised of inlet and outlet temperature sensors, flow meter and data logger) are readily available to meet the standards for accuracy, durability, backup power and operation cited in the Section 6.2 below. Digital controllers for larger systems may have heat metering functionality built in. As long as it capable of meeting the specifications for dedicated heat meters described in section 6.2 it will be an acceptable form of continuous metering. The basic equation for collector loop heat generation is:

Q_g = m*cp (To –Ti)

Q_g = heat generated in the collector loop (BTU)

m = mass flow of the collector working fluid measured near the inlet to the solar storage tank (lbs/hour)

cp = specific heat of the working fluid (Btu/lb-F)

Ti = collector loop inlet temperature measured near the outlet of the solar storage tank (F)

To = collector loop outlet temperature measured near the inlet to the solar storage tank (F)

As long as collector loop outlet flows and temperature are measured near the storage tank, thermal losses due to collector over-temperature protection will be embedded in the measurement. Details on applicable standards are provided in Section 6.2 below.

6.1.2 CONVERSION TO USEFUL HEAT OUTPUT

Critical conversion factors to be measured/determined at system commissioning include coefficients for thermal storage heat loss and collector loop pump demand. Average values for tank heat losses and pump energy consumption will be determined in the commissioning test and verified by comparing to OEM specs for the equipment.

STORAGE HEAT LOSSES

The coefficient of heat loss for the storage can be determined for the as built system during the performance test procedure cited in Section 6.2 below. The basic equation for the storage heat loss coefficient is:

dHF/dt (solar) = $(T_{set} – T_2)/(T_{set}-T_{in})(t_2-t_1)$

dHF/dt = rate of change in storage enthalpy capacity (fractional loss/hr)

T_{set} = Temperature set point for storage - temperature at the start of the test (F)

T_2 = Temperature at the end of the test (F)

T_{in} = Temperature of makeup water at the tank Inlet

t_1 = Time at the start of the test (hr)

t_2 = Time at the end of the test (hr)

However the accuracy of the test is dependent on the length of time that the test is conducted and the time afforded to a commissioning performance test will be a few hours to be practical. The alternative is to rely on the hot water tanks performance certification under the AHRI Certification Program. Thermal storage standby loss factor (SLF) can be easily and reasonably accurately estimated from the storage tank manufacturers AHRI certification data for the Energy Factor (EF) and Recovery Efficiency (RE):

SLF = 1- EF/RE

If no certification exists for the tank or the tank thermal performance has been upgraded on-site then the on-site test procedure can be performed to measure the as-built tank thermal performance.

SOLAR LOOP PUMPING POWER

The coefficient for loop pumping power consumption will be determined for the as built system during the performance test procedure cited in Section 6.2 below. The basic equation for pump energy coefficient is:

dE/dQ = Vm*Am * t /Qg

dE/dQ = Rate of electrical energy consumed by the pump per unit of heat generated (Wh/BTU)

Vm = measured voltage at the pump terminals (Volts)

Am = measured current flow to the pump averaged for the test period (Amps)

Q_g = heat generated/extracted in the collector loop for the test period (BTU)

t = total time in the test period (hours)

GENERAL EQUATION FOR CALCULATING USEFUL THERMAL ENERGY

The final general form of the equations for determining useful thermal energy produced by solar thermal system is:

Q_u (net) = Q_g – Q_g*dHF/dt (tank) *t - Q_g*dE/dQ(pumps)*k

or using the storage tank certification data

Q_u (net) = Q_g – Q_g*SLF(tank) - Q_g*dE/dQ(pumps)*k

Where:

Q_u (net) = Net useful thermal energy delivered (BTU)

Q_g = useful energy generated in the collector loop (BTU)

dHF/dt (tank) = rate of change in storage enthalpy capacity (fractional loss/hr)

t = total time during the current reporting period (hr)

SLF(tank) = Standby Loss Factor for the thermal storage tank

dE/dQ(pumps) = Rate of Energy consumed by collector loop pump per unit of heat generated (Wh/BTU)

k = 3.412 BTU/Wh direct conversion factor

For multi tank systems where the solar heat transfer fluid is separately stored from the potable or process hot water tanks the storage heat loss pumping power coefficients for the solar tank and the solar heat exchanger loop respectively also must be measured using the same forms of equations above.

6.2 RELEVANT CURRENT AND PENDING STANDARDS

6.2.1 CONTINUOUS HEAT METERING FOR LIQUID PHASE HYDRONIC SOLAR THERMAL SYSTEMS

The most comprehensive and appropriate standard for the performance and maintenance of the heat metering system is EN 1434 published by CEN. It is appropriate because the intent of the developers of a new U.S. standard is to essentially duplicate the key specifications of the European Standard. Once the new ASTM standard is published it should supersede the CEN standard for purposes of the RPS program. The CSI program has created the most comprehensive guide to locating the sensors and meters for heat metering. This guide should be amplified in a similar guide for the NH program to specify details of the continuous metering installation.

6.2.1 CONVERSION TO USEFUL HEAT OUTPUT

To verify the collector loop performance as built and determine the heat loss and pumping power coefficients for the system, a performance test during system commissioning will be required. The standard ***ISO 9459-2: Outdoor Test Methods for System Performance Characterization*** provides a well-designed certification test procedure for hot water systems. The commissioning performance test procedure prescribed for the thermal RPS is a much simplified procedure that used ISO 9459 as a guide only.

6.3 RECOMMENDATIONS ON METERING IMPLEMENTATION

6.3.1 SOLAR THERMAL LIQUID PHASE HYDRONIC SYSTEMS IMPLEMENTATION

The proposed implementation method for metering useful energy output from Solar Thermal liquid phase systems including antifreeze protected systems consists of the following steps:

System Commissioning Performance Test - As an integral part of the system commissioning process a system performance test will be performed as prescribed in Appendix NN. The test purpose is three-fold: first to determine for the owner that the system performs as certified or warranted, second to determine the heat meter is calibrated and working as designed and third to measure the storage heat loss and pump energy consumption coefficients that will be used to calculate net useful energy output from the metered collector loop heat generation.

System Test Report - The system vendor/commissioner will prepare a one page report for the results of performance test in the format of the template provided in Appendix NN to this report.

Quarterly Heat Generation Reporting – the quarterly report (template in Appendix MM) will consist of a summary REC invoice reporting the total eligible useful heat production of the period, a narrative describing meter calibrations performed and any issues with meter operation or recording, and supporting spreadsheets calculations for determining net useful thermal energy generation for the period.

Annual System Calibration and Performance Test – Each year the performance test will be repeated and an estimate of yearly production based on test results will be compared to the reported heat generation for that period.

6.3.2 MODIFICATION TO ALLOW FOR PROVISIONAL METHODS FOR RESIDENTIAL SCALE DHW SYSTEMS UNDER 30 kW_T

An alternative approach to metering residential scale DHW systems would substitute the continuous metering of the run time for the solar system for the standard metering provisions described in this section. Electrical hour meters are inexpensive and easy to install. Placed on the pump circuit for the collector array they can accurately track the run time for the heat generation subsystem. Actual heat generation would be then calculated based on the collector annual average thermal energy generation rate.

$dH/dt = Q_{yr}/T_{op}$

dH/dt = Annual average thermal energy generation rate. (BTU/hr)

Q_{yr} = the SRCC predicted solar array energy output for a year under average NH meteorological conditions BTU

T_{op} = the SRCC predicted run time of the system for a year under average NH meteorological conditions (hr)

Total energy generation for each reporting period would be calculated as:

$Q_u = dH/dt*Tm$

Tm = equals metered run time for the period in hours

The system would undergo the same simplified version of the ISO 9459 performance test to verify the system average heat generation rate and determine the coefficients for storage heat loss and pump energy consumption. All other steps for implementation would be as prescribed in Section 6.3.1 above.

7 RESIDENTIAL AND COMMERCIAL GEOTHERMAL SYSTEMS

7.1 METERING TECHNOLOGY AND THERMAL OUTPUT CALCULATIONS

The method prescribed for geothermal heat pump systems consist of two distinct parts:

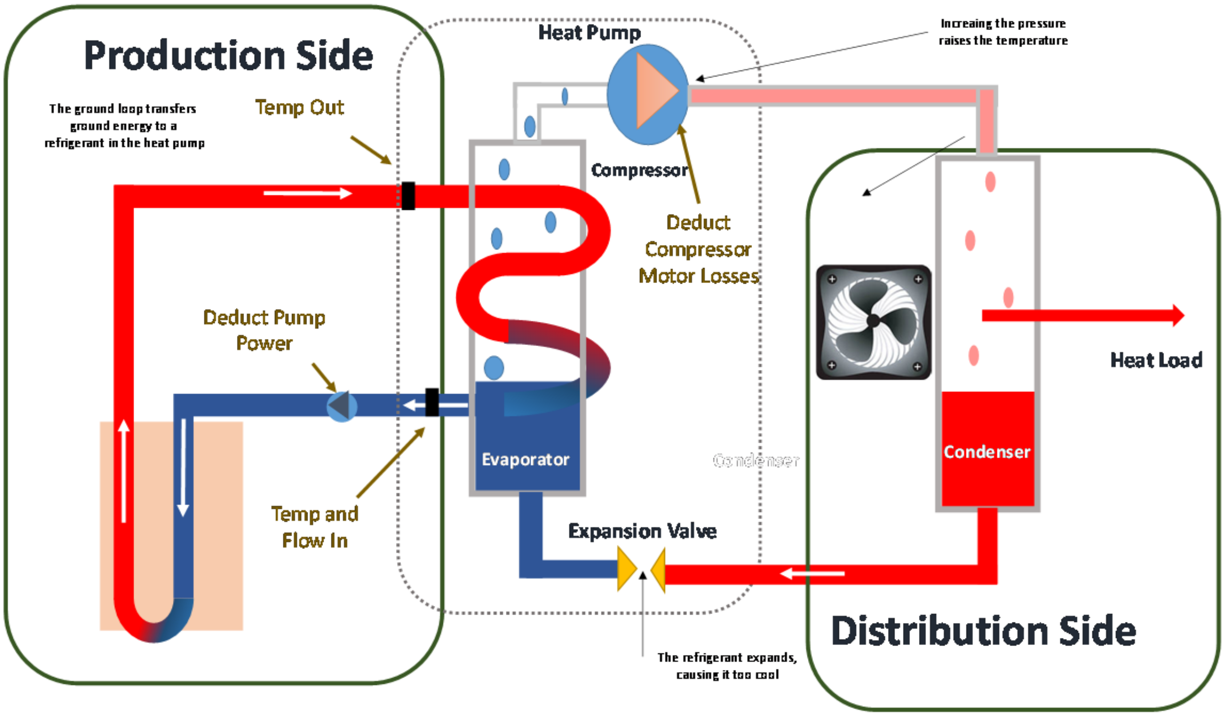
1. Continuous metering of thermal energy generated by the geothermal ground loop
2. On site measurement of the operating power inputs to enable calculation of the net useful thermal energy produced by the system

U.S. Customary and SI units of measure for the equations in this section will both be provided in Appendix XX summarizing all computations prescribed in this report.

7.1.1 CONTINUOUS HEAT METERING FOR LIQUID PHASE GROUND LOOP GEOTHERMAL HEAT PUMP SYSTEMS

This category encompasses water-based systems with or without antifreeze. The recommended control volume for continuous metering for geothermal systems is the ground loop.

Exhibit 5: Ground Source Heat Pump



Continuous metering requirements are straightforward. Ground loops typically operate at fluid temperatures in the range of 20 to 90 degrees F. Packaged and combination heat meters (comprised of ground loop inlet and outlet temperature sensors, flow meter and data logger) are readily available to meet the standards for accuracy, durability, backup power and operation cited in the Section 7.2 below. Digital controllers for larger systems may have heat metering functionality built in. As long as it meets the specs for dedicated heat meters described in section 7.2 it will be an acceptable form of continuous metering. The basic equation for ground loop heat input is:

Q_g = m*cp (To –Ti) in heating mode, m*cp (Ti –To) in cooling mode

Q_g = heat generated/extracted in the ground loop (BTU)

m = mass flow measured near the inlet to the heat pump heat exchanger (lbs/hour)

cp = specific heat of the working fluid (Btu/lb-F)

Ti = ground loop inlet temperature measured near the heat pump heat exchanger (F)

To = collector loop outlet temperature measured near the heat pump heat exchanger (F)

Details on applicable standards are provided in Section 7.2 below.

7.1.2 ELECTRICAL ENERGY CONSUMED TO PRODUCE USEFUL HEAT OUTPUT

The critical conversion factor to be measured at system commissioning is the ground loop pump power demand. Average values for power consumption will be determined based on results of the commissioning performance test and verified by comparing to OEM specs for the equipment.

GROUND LOOP PUMPING POWER

The coefficient for ground loop pumping power consumption will be determined for the as built system during the performance test procedure. The basic equation for the ground loop pump energy coefficient is:

$dE_p/dQ = V_m * A_m * t / Q_g$

dE_p/dQ = Rate of Energy consumed by ground loop pump per unit of heat generated (Wh/BTU)

V_m = measured voltage at the pump terminals (Volts)

A_m = measured current flow to the pump averaged for the test period (Amps)

Q_g = heat generated/extracted in the ground loop for the test period (BTU)

t = total time in the test period (hours)

GENERAL EQUATION FOR CALCULATING USEFUL THERMAL ENERGY

The final general form of the equation for determining useful thermal energy produced by geothermal system is:

$Q_u(\text{net}) = Q_g - Q_g * dEp / dQ * k$

Q_u(net) = Net useful thermal energy delivered (BTU)

Q_g = useful energy generated/extracted in the ground loop (BTU) in each season

dE_p / dQ= Rate of Energy consumed by ground loop pump per unit of heat generated (Wh/BTU) k = 3.412 BTU/Wh direct conversion factor

7.1.3 ACCOUNTING FOR COMPRESSOR ENERGY INPUTS

The compressor performs a unique role in the heat pump. The work performed by the compressor not only generates useful heat but it also raises (lowers in cooling mode) the temperature of the refrigerant to a level necessary for heat transfer to the hydronic or air systems that distribute energy (extract energy in cooling mode) to (from)the facility thermal loads. For this reason it is recommended that the PUC consider allocating a portion of the compressor motor energy losses (electrical and mechanical only) to the geothermal source.

EQUATION FOR ALLOCATING COMPRESSOR MOTOR LOSSES

Only a portion of the mechanical and electrical losses for the compressor motor should be debited from the ground loop thermal generation. The heat pump OEM should provide the combined electrical (motor) and mechanical (shaft) energy loss factors for the compressor. The allocation of losses should be based on the ground loops percent of total useful heat generated by the ground loop and compressor. The equation for the allocation of losses to the useful heat generated from the ground Loop is:

$Qg/Qt = (COP-1)/COP$ where $COP = EER/3.412$ for the cooling season

Qg/Qt = ratio of ground loop heat input (or extraction) to the total heat pump useful heat generated (or extracted)

COP and EER are measured at AHRI standard certification conditions.

$COP = Qt/Qe$ = ratio of total heat input to the thermal equivalent of heat pump electrical energy input at rating conditions

The equations for allocation yield the total seasonal allocation factor:

$F_{cl} = Qg/Qt$

Separate seasonal allocation factors must be determined for the heating and cooling season.

COMPRESSOR MOTOR ENERGY LOSSES

The Coefficient of Compressor Motor Energy Losses can be deducted for the as built system using the following equation:

$dE_{cl}/dQ = V_m * A_m * t * f_{me} / (Qg * F_{cl})$

dE_{cl}/dQ = Rate of electrical and mechanical energy lost by heat pump compressor motor per unit of heat generated (or extracted) by the ground loop (Wh/BTU)

V_m = measured voltage at the compressor motor terminals (Volts)

A_m = measured current flow to the compressor motor averaged for the test period (Amps)

t = total time in the test period (hours)

Q_g = heat generated/extracted in the ground loop for the test period (BTU)

The combined electrical and mechanical loss factors can be calculated from data provided by the OEM:

$f_{me} = 1-f_e * f_m$

f_{me} = compressor motor energy loss factor

f_e = motor electrical efficiency at full load

f_m = shaft mechanical efficiency at full load

F_{cl} = factor for allocation of compressor electrical and mechanical losses to ground loop generation.

Separate coefficients should be calculated for the heating and cooling season.

GENERAL EQUATION FOR CALCULATING USEFUL THERMAL ENERGY

The final general form of the equation for determining useful thermal energy produced by ground loop is:

$Q_u(\text{net}) = Q_g - Q_g * dEp/dQ * k - \sum_{\text{heating}} Q_g * dE_{cl}/dQ * k - \sum_{\text{cooling}} Q_g * dE_{cl}/dQ * k$

Q_u(net) = Net useful thermal energy delivered (BTU)

Q_g = useful energy generated/extracted in the ground loop (BTU) in each season

dE_p/dQ= Rate of Energy consumed by ground loop pump per unit of heat generated (Wh/BTU)

dE_{cl}/dQ = Rate of electrical and mechanical energy lost by heat pump compressor per unit of heat generated by the ground loop (Wh/BTU)

k = 3.412 BTU/Wh direct conversion factor

It is expected that the average values of the coefficients for compressor power losses will vary by season and the summations indicate that the seasonal coefficients (heat and cooling) are applied to the sum of seasonal heat generated by the ground loop in the reporting period. This is not a large correction to the useful heat generation in a well-designed system and could be excluded in the interests of simplifying the accounting and reporting process.

7.2 RELEVANT CURRENT AND PENDING STANDARDS

7.2.1 CONTINUOUS HEAT METERING FOR LIQUID PHASE GROUND LOOP GEOTHERMAL SYSTEMS

The most comprehensive and appropriate standard for the performance and maintenance of the heat metering system is EN 1434 published by CEN. It is appropriate because the intent of the developers of a new U.S. standard is to essentially harmonize with the key specifications of the European Standard. Once the new ASTM standard is published it should supersede the CEN standard for purposes of the RPS program. The CSI program has created the most comprehensive guide to locating the sensors and meters for heat metering. This guide could be used as a model for a similar guide for the NH program to specify details of the continuous metering installation.

7.2.2 CONVERSION TO USEFUL HEAT OUTPUT

To verify the ground loop performance as built and determine the pumping power coefficients for the system, a performance test during system commissioning will be required. On January 1, 2000, a new standard (ISO standard 13256) replaced two earlier standards (ARI 325 and ARI 330) used to rate the efficiency of GSHPs. This standard was established to support the rating and certification of the heat pump subsystem and therefore provides only limited useful guidance for the thermal energy generation performance test. Applicable portions of this standard are cited in the outline of the one day on-site performance testing required by the thermal metering methodology.

7.3 RECOMMENDATIONS ON APPROACHES

The proposed implementation method for metering useful energy output from geothermal liquid phase ground loop systems including antifreeze protected systems consists of the following steps:

System Commissioning Performance Test - As an integral part of the system commissioning process a system performance test will be performed as prescribed in Appendix NN. The test purpose is three-fold: first to determine for the owner that the system performs as certified or warranted, second to determine the heat meter is calibrated and working as designed and third to measure ground loop pump and heat pump compressor motor energy use coefficients necessary to the production of useful heat from the ground source. These factors will be used to calculate net useful energy output from the metered ground loop heat generation.

System Test Report - The system vendor/commissioner will prepare a one page report for the results of performance test in the format of the template provided in Appendix NN to this report.

Quarterly Heat Generation Reporting – the quarterly report (template in Appendix MM) will consist of a summary REC invoice reporting the total eligible useful heat production of the period, a narrative describing meter calibrations performed and any issues with meter operation or recording, and supporting spreadsheets calculations for determining net useful thermal energy generation for the period.

Annual System Calibration and Performance Test – Each year the performance test will be repeated and an estimate of yearly production based on test results will be compared to the reported heat generation for that period.

8 LARGE AND SMALL BIOMASS RENEWABLE ENERGY TECHNOLOGIES

Metering the useful thermal energy for biomass systems is different in several respects to the strategies presented for solar thermal and geothermal technologies.

1. The scale of biomass projects has the potential to be relatively large;
2. Especially at larger scales, biomass energy projects are likely to include simultaneous production of heat and electricity (CHP); and
3. Stack gas waste heat recovery for productive use may be incorporated into some systems.
4. It is possible that the system can produce energy eligible for both the thermal and electric RPS programs

For large projects, the cost of installing the necessary metering and instrumentation will be (as a portion of overall capital investment) small and in some cases will be required to comply with energy service contracts or operations. Fundamentally, many of the principles discussed in previous sections still apply. Most importantly, the measurements necessary to determine useful eligible thermal energy include gross thermal output and accounting of energy deductions for a variety of factors to be explained below.

With respect to useful thermal energy output, there are several options which are irrespective of the biomass fuel source. Two reasonably common options are as follows:

1. Measure the amount of heat added to the biomass energy conversion device (BECD, e.g. boiler, gasifier, or engine) and use an efficiency figure to calculate the amount of useful energy generated in the form of steam/hot water or hot gas.
2. Directly measure the energy leaving the biomass energy conversion device using flow, temperature and pressure instrumentation.

A few of the key issues with the first option are as follows:

1. Unlike gas- or oil-fired systems, common biomass energy systems will not have the benefit of utilizing fuels with steady and standardized heating values or hydrocarbon compositions. Exceptions potentially include some liquid biofuels (such as biodiesel) and methane rich biogas (such as anaerobic digestion or landfill gas), but these systems remain relatively uncommon and in the case of the latter, still subject to some compositional volatility. Systems that rely on pellet fuels will be more consistent than those that rely on wood chips, but heating value for the pellets will still vary considerably more than is typical for pipeline quality gas or heating oil. This makes calculating heat input (whether by fuel mass flow or stack gas flows) subject to potentially significant uncertainty, thereby complicating the use of this method.
2. Even under the best of conditions, boiler efficiency is not static. Boiler efficiency will be impacted by thermal load, boiler condition and operating parameters. To be useful in derivative calculations, either an average efficiency or real-time and sophisticated monitoring must be employed to use these data.

Directly measuring biomass system energy output might eliminate some of these issues, but this options remains dependent on the accuracy and collaboration of the required instrumentation and complex metering may be required for certain project configurations. In some cases, this may also include heavily redundant instrumentation to ensure that key data is never missed. Even during well maintained and steady operation, ensuring that a large number of instruments are operating within tight specifications can be challenging when the focus of plant personnel is keeping the plant running. Instrumentation that is not critical to operations may be viewed as operating "well enough," which may not be sufficient for precise measurements. A good example of this is the tendency of many facilities to let steam flow meters drift outside of calibration or to be operated well outside of their turn down range.

Obviously more instrumentation also means that upfront costs may be higher with this approach. Fortunately, the systems that will require the most instrumentation (large-scale CHP projects) are probably also the most likely to install and maintain sophisticated meters and gauges in support of their operations.

On the positive side, for the most part the uncertainty of the direct measurement of thermal energy can be adequately characterized based on equipment capabilities/specifications and the uncertainty of fuel heating values is avoided. Based on this, for wood-fuelled systems, it seems prudent to focus on directly measuring the energy in the working fluids themselves. Since direct measurement of key thermal flows is also possible with other biomass-fuelled systems and since a consistent treatment across technologies is desirable, a direct measurement approach is recommended universally for biomass systems under the New Hampshire RPS.

Regardless of which approach is used in measuring gross biomass energy conversion system thermal output, measurement of useful thermal energy will require measuring several other aspects of the overall energy delivery system:

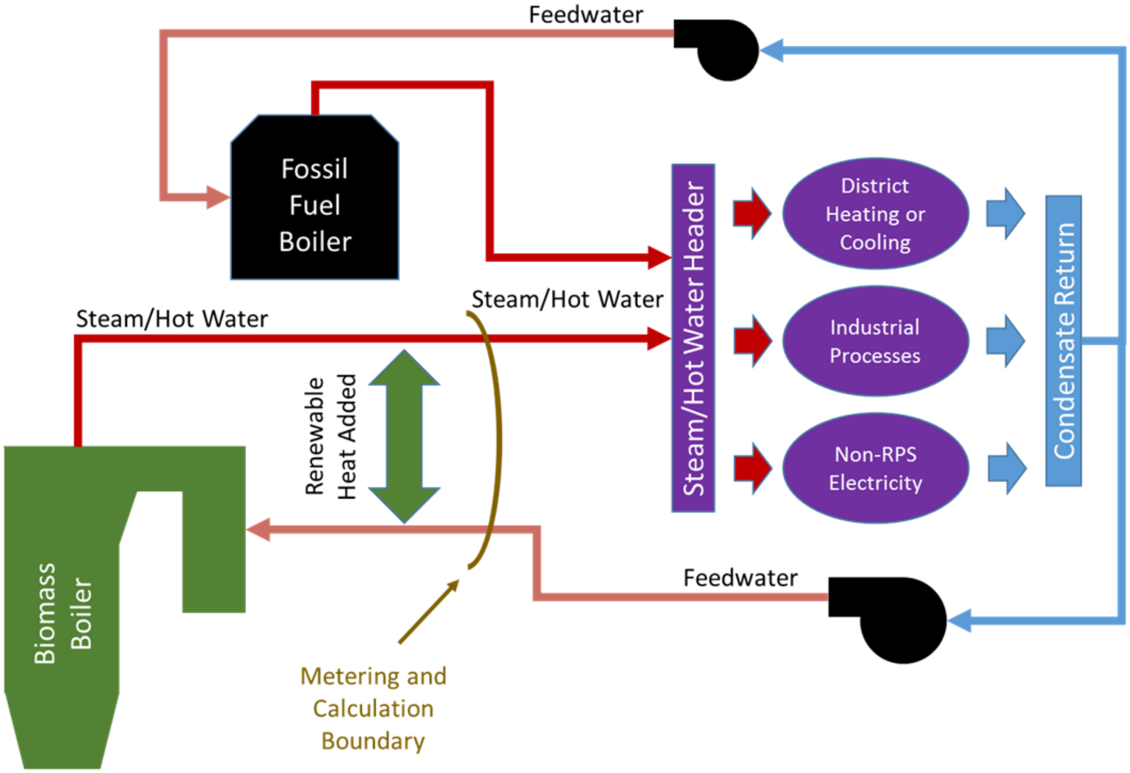
1. Energy leaving biomass energy conversion device;
2. Amount of useful energy returned to the system by the thermal process or load (e.g. condensate);
3. Energy input into the system by non-eligible energy sources (other boilers, electricity, etc.); and
4. Energy used to produce compensated renewable electricity (CHP case).

8.1 METERING TECHNOLOGY AND THERMAL OUTPUT CALCULATIONS

For CHP projects there are two fundamentally different cases to consider. If RECs generated by electricity production are not purchased under the NH RPS program then the entire amount of useful thermal energy produced from biomass should be eligible for the NH thermal RPS program. If RECs generated by the electricity production are purchased under the NH RPS program and the PUC rules prohibit double compensation, then the useful thermal energy used for process heat must be accounted for separately for purchases under the NH thermal RPS program. The diagram below provides the conceptual design of the recommended heat metering approach for the first case which is designated as the baseline system. In this case, the steam turbine can be treated as if it is just another industrial end-use, and no special correction to the proposed measurement of useful thermal energy is required. In the second case, electric generation receiving payments under the RPS program, the measurement of useful thermal energy must be handled differently. Treatment of thermal energy from waste heat recovery is also treated as a special case.

Exhibit 6 offers a diagram of key elements of a biomass energy steam or hot water system.

Exhibit 6: Biomass Metering Overview



BIOMASS BASELINE THERMAL METERING CONCEPT

Note that not all elements in Exhibit 6 will be present in all systems, but the diagram is helpful in demonstrating the following principles:

- The net heat addition or "useful thermal" energy output of the system can be generally taken as the difference between the amount of thermal energy leaving the biomass energy device (example shown is a boiler) and the amount of energy returned from the load being served and fed back to the system. The process loads served by the energy system can be diverse including industrial processes or heating for a school. The proposed measuring point for future calculations is the boiler energy output at a point as close as practical to the distribution point of the thermal energy. In the case shown, this would be just upstream of the hot/water or steam header.
- Another complicating factor is the "parasitic" load. Parasitic loads take energy from the system and redirect it elsewhere in the system. They include energy to heat feedwater, deaerate the feedwater (oxygen removal) and control steam production. In general, they do not represent heat loss to the system. To the extent that these loads are completely inside the metering boundary, they are not an issue since the meter will never see those flows and they are

effectively netted out. However, if they are downstream (outside the metering boundary) and their energy is not returned back to the system in a way that the metering recaptures that energy use, they may be incorrectly counted. Likewise, thermal energy that is taken from behind the outbound metering point and used before the before the meter measuring inbound energy will require special treatment. A medium- to large-scale plant may have a number of these parasitic loads and it would be complicated and expensive to meter them so an alternative is offered to account for them in the calculation section below.

There are potentially a number of non-renewable energy inputs into the system that must be excluded or deducted from the metered thermal energy. These include items such as a fossil-fired boiler operating in parallel to help meet thermal loads. This may or may not be an issue depending on the plant configuration and this is discussed in more detail later.

In Exhibit 6, any electricity generated as part of the process was assumed not to receive compensation for RECs under the New Hampshire RPS. There might be a variety of reasons for this, including that the eligible electricity may be already destined for another market. However, it is just as likely that a larger, steam-based biomass plant will include electric generation that is eligible for REC payments under the New Hampshire RPS and that selling the eligible energy as an electrical REC rather than as a thermal REC would be more desirable. This presents a potential problem with double counting. Exhibit 7 offers a look at this scenario in more detail. In this scenario a turbine is inserted ahead of the main steam header[5] and all steam is directed through the steam turbine. Depending on the type of turbine used:

1. All of the steam will pass through the turbine and will be lowered to a distribution pressure for downstream use, or
2. Part of it will be lowered to distribution pressure and the balance will be reduced to very low pressures (including to a vacuum) to maximize electricity generation. The case shown below best illustrates this case.

In either case, the energy extracted from the steam to produce the RPS compensated electricity must be netted out to avoid double counting. There are several options for achieving this objective and the calculations needed are described in subsequent sections.

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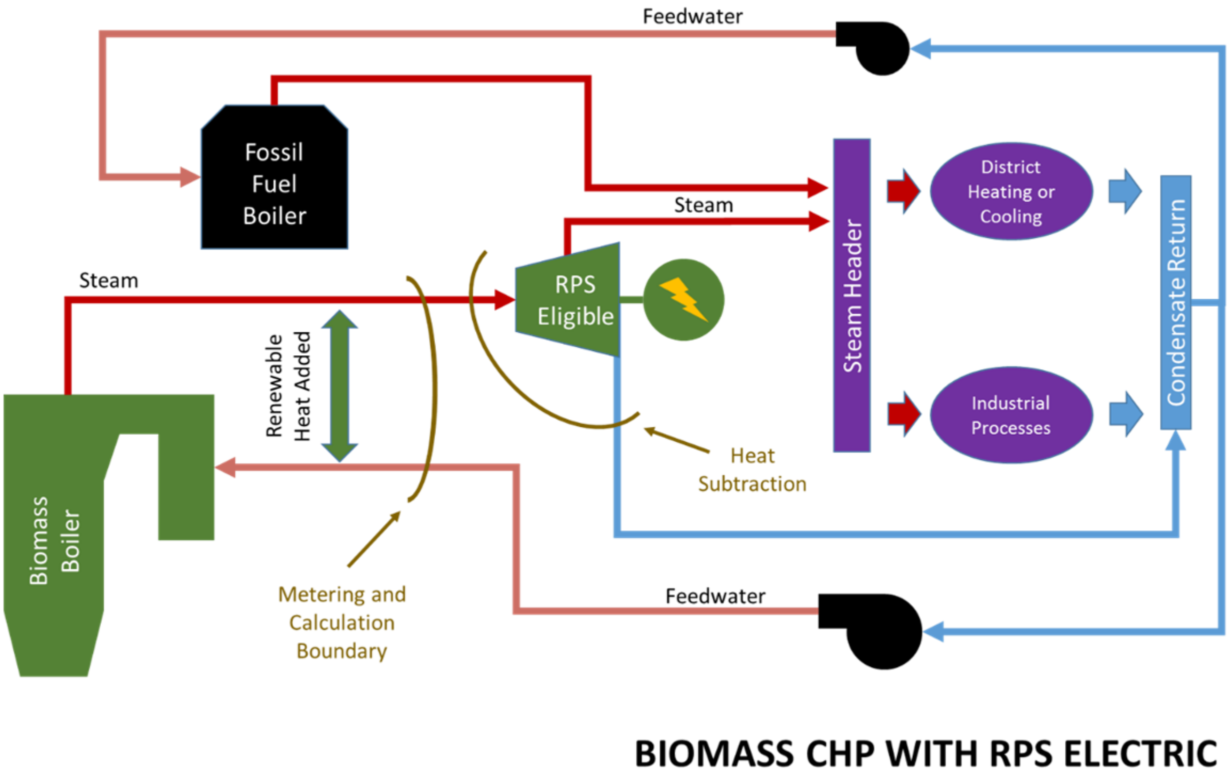
[5] Note that this scenario is presumed to use steam as the working fluid and is more specific than the general case offered in Exhibit 6, which could use steam or hot water.

Exhibit 7: Biomass Metering Design for RPS Compensated Electricity Generation

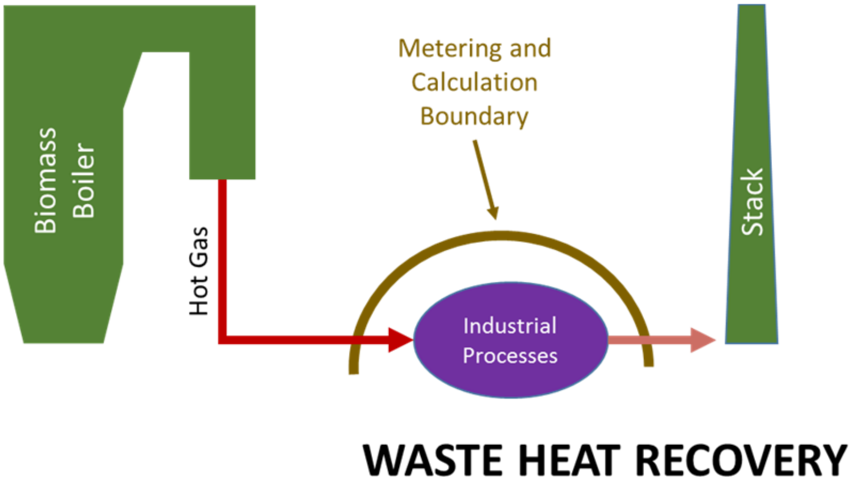


In addition to the above, some systems may incorporate waste heat recovery from combustion gases for industrial processes. In fact, most large-scale (any many smaller ones) biomass systems do recover some waste heat from combustion gases. This can include the use of air pre-heaters, economizers or flue gas recirculation. These processes are intended to improve fuel efficiency or emissions performance and are internal to the process of increasing energy in the water or steam. Therefore, the usefulness of the recovered energy is already accounted for inside the proposed metering boundaries and no additional accounting is required in these situations.

However, there are some circumstances when waste heat is put towards external use. The type of use will depend on stack gas flow rates and temperatures, but could include drying fuel wood or lumber. With respect to evaluating the useful heat provided by such systems, some caution should be exercised. For example, if a facility is drying its own wood fuel, this is more consistent with a parasitic energy use and the recovered thermal energy is being used to improve the efficiency of the energy conversion process. However, if the heat is being used to upgrade a product (lumber drying) or for some other process then it certainly qualifies as useful thermal energy as defined in the RPS program.

Exhibit 8 offers a simplified diagram overview of this concept. As shown, the difference in energy in the combustion gas before and after the intended use is regarded as "useful." Any heat that travels up and out the plant stack is wasted and is not useful. This application essentially requires an additional and separate metering system. The requirements for metering and calculating useful energy for these cases are provided in a subsequent section.

Exhibit 8: Biomass Metering Overview - Waste Heat Recovery



There are wide variety of potential project configurations possible with biomass energy systems, especially at larger scale. However, the principles illustrated above are general enough to cover most of them. For example, a reciprocating engine fired with biodiesel can be used to generate eligible RECs and useful thermal energy. Depending on the use of that energy, it can be fully described as either waste heat recover (Exhibit 8) or under the "heat only" scenario described in Exhibit 7.

This section details the calculation methodologies for evaluating the useful thermal energy from biomass energy systems. Although details are provided for the three cases presented above, all rely on the following general equation:

Equation 1: $U_{th} = Q_{out} - Q_{ret} - Q_{rps} - Q_{adj} - Q_{par} + Q_{wh}$**; where**

U_{th} = useful thermal energy (Btu/hr)[6]

Q_{out} = energy leaving BECD (Btu/hr)

Q_{ret} = energy returned from process (Btu/hr)

Q_{adj} = energy adjustment for non-renewable energy inputs (Btu/hr)

Q_{par} = energy adjustment for parasitic loads downstream of Q_{out} metering point (Btu/hr)

Q_{RPS} = thermal energy used to produce RPS compensated electricity (Btu/hr)

Q_{wh} = waste heat recovered from exhaust gas (Btu/hr)

8.1.1 BIOMASS HEAT ONLY / NON-RPS ELECTRIC GENERATION

The situation where the BECD is supporting a simple district heating or small industrial process is representative of the baseline case. As the downstream processes become more complicated or includes electrical generation, the requirements for calculating useful thermal energy increase. Fortunately, these can be handled as adjustments that are added to the baseline scenario.

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[6] Strictly speaking, the equations shown are representative of system "thermal power" not energy. However, the term "energy" is adopted to avoid confusion with a broader audience and to stay consistent with language used in the enabling statute.

For the baseline case which does not include non-renewable energy inputs, waste heat recovery or eligible renewable energy generation; Equation 1 is simplified to the following:

Equation 2: $U_{th} = Q_{out} - Q_{ret} - Q_{adj} - Q_{par}$

The calculations needed to compute the needed values for this baseline scenario will vary depending on whether steam, hot water or another substance[7] is serving as the working fluid. In general Q_{out} will be calculated as follows:

$Q_{out} = m_{out} * (h_{out})$; where

m_{out} = mass flow (lbm/hr) metered upstream of distribution and downstream of parasitic loads

h_{out} = specific enthalpy (Btu/lbm) at metering point

For liquid water phase systems (e.g. hot water), h_{out} will be a function of temperature $h_{out}(t)$.

For water vapor phase systems (e.g. steam), h_{out} will be a function of temperature, pressure or both $h_{out}(t,p)$. Note that for saturated steam systems, even though only one parameter is needed to calculate the specific enthalpy, both will be required to verify the absence of superheat at the measurement point. For superheated systems, both pressure and temperature measurements will be required.

Regardless of phase, the enthalpy under the measured conditions will either be calculated using IAPWS[8] -IF97 formulas or looked up via steam tables.

Energy returned from the process is calculated in a similar manner. However, energy will be returned in liquid phase (condensate), heated and fed to the boiler. The location for the metering point is after the feedwater pumps.

Q_{ret} (Btu/hr) = $m_{ret} * (h_{ret})$; where

m_{ret} = mass flow (lbm/hr) metered downstream of feedwater pumps as close to BECD as possible

h_{ret} = specific enthalpy at metering point (Btu/lbm), where h_{ret} will be a function of Temp $h_{ret}(t)$.

An adjustment must also be made to avoid double counting any parasitic loads which are downstream of a main energy distribution header and are used for plant internal functions. Ideally, any parasitic load which falls into this category would be metered and accounted for separately such that the sum of the parasitic energy could be netted out of the useful thermal energy output calculation in real time. However, this may be very impractical or difficult to justify economically. Fortunately, many of these parasitic loads[9] are likely to be related to items which are generally proportional to the system's energy output. For this reasons, it is recommended that an average parasitic demand be measured using system data and calculated as proportion of Q_{out}.

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[7] Some developers have proposed using Organic Rankine Cycles which use working fluids other than water. This case is not considered explicitly here, but the principles are the same. However, some of the calculations will be different since only hot water and steam are shown.

[8] International Association for the Properties of Water and Steam

[9] For the purposes of this analysis, it is assumed the energy flows dedicated to space heating can be calculated on an average annual basis and then allocated back monthly. It is also possible to prepare monthly heating load estimates and add to the parasitic load calculations accordingly. Lastly, the use of dedicated metering may be possible and desirable in some circumstances. The use of metered data to correct for heating loads is also reasonable.

Special treatment may be required for in situations where parasitic thermal energy (e.g. feedwater heating) is extracted prior to the Q_{out} meter point and moved to a point prior to the Q_{ret} meter. In this case the thermal power crosses the metering boundary in the way that requires correction, but instead of subtracting this energy (which is required when useful thermal energy leaves the system), this energy must be added back in the calculation. Alternatively and preferentially, it may be more convenient to move the Q_{out} metering point so that it proceeds the thermal extraction, which avoids the issue.

The process for calculating for thermal parasitic loads is the same regardless of the situation. However, the signs for the equation are reversed depending on which type of parasitic load is being adjusted.

Equation 3: $Q_{par} = P_{load} * Q_{out}$; **for parasitic loads that extract energy from system**

Equation 4: $Q_{par} = -1*(P_{load} * Q_{out})$; **for parasitic energy moved across metering boundary**

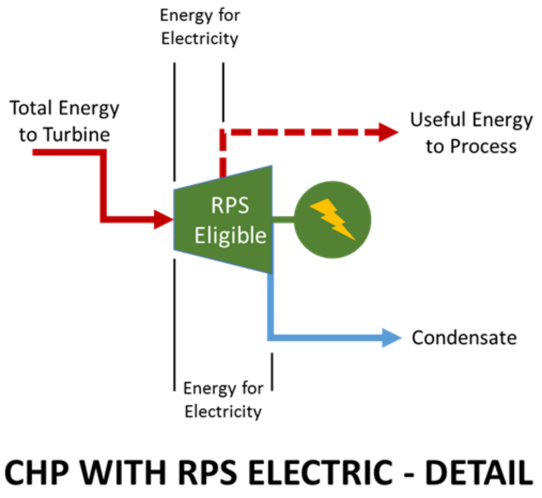
P_{load} is measured or calculated using following general procedure.

1. Identify affected parasitic thermal loads;
2. Use existing best practices for plant energy audits to quantify these loads as a percentage of Q_{out} including using available flow, pressure and temperature measurements. If required, temporary measurements from external instruments or use of available instrumentation wells may be needed.
3. For items such as feedwater heaters or deaerators, manufacturer performance data may be used to augment data needed to perform necessary calculations.

8.1.2 ADJUSTMENT FOR RPS COMPENSATED ELECTRIC GENERATION

A site which generates RPS compensated generation represents a special case. In this case, energy output from the BECD has the potential to be double counted in the RPS program, receiving credit as a thermal and an electric REC. Conceptually, accounting for this situation requires that the thermal energy used to generate the qualifying electricity be subtracted from the useful thermal output of the system. Although there are potentially several ways this may be accomplished, Exhibit 9 offers an explanation of the recommended approach:

Exhibit 9: Compensated RPS Electricity Accounting



There are variety of potential configurations for steam turbines in a complex industrial plant. The example shown above is intended to illustrate a few of the more common including a backpressure turbine (steam pressure is reduced to meet a process), a condensing turbine (only power is produced) and a combination of these either through a condensing extraction turbine or multiple turbines. The important point of the illustration above is that the thermal energy for generating electricity should be separated from the thermal energy that is used to generate electricity. Further, in the case of a system with a condensing turbine (or stage) the condensate energy is recovered and returned to the process. Therefore calculation of necessary useful thermal energy adjustment (Q_{RPS}) follows:

$Q_{Tin} = Q_{RPS} + Q_{process} + Q_{Toutj}$; or

$Q_{RPS} = Q_{Tin} - Q_{process} - Q_{Tout}$; where

Q_{RPS} = the total energy extracted to generate RPS compensated electricity;

Q_{Tin} = the total energy flowing to the turbine inlet;

$Q_{process}$ = the total energy extracted or discharged from the turbine for downstream process use;

Q_{Tout} = the total energy flowing from the turbine as condensate; and

Q_{Tin} (Btu/hr) = $m_{ST} * h_{ST}$; h_{ST} (t,p)

$Q_{process}$ (Btu/hr) = $m_{process} * h_{process}$; $h_{process}$ (t,p)

Q_{Tout} (Btu/hr) = $(m_{ST}-m_{process})*h_{Tout}(t)$

Q_{RPS} is then used as shown in Equation 1 and ensures that thermal energy used to generate compensated electricity RECS is not double counted.

8.1.3 ADJUSTMENT FOR WASTE HEAT RECOVERY

Referring back to Exhibit 8, it is possible that some industrial processes will attempt to make use of waste heat for purposes other than improving BECD conversion efficiency. There are practical limits on this approach as cooling exhaust gases down too far can create maintenance, operation and environmental issues for the plant. However, in cases where stack gas heat recovery can be employed, calculating the positive adjustment for the heat recovery will depend somewhat on the downstream process. In situations where the exhaust gas is used directly (i.e. there is no heat exchange to another working fluid) then measuring the energy difference in flue gases before and after the process is a reasonable means of calculating the additional useful heat. However, if a heat exchange is used (to produce hot water for example), then the same principals used in calculating the useful heat for the for the baseline case (refer to Exhibit 6) is more appropriate. Conceptually, one can imagine that the waste heat becomes the “renewable energy” input to a subsequent BECD and one can follow the equations established above for calculating useful thermal energy output accordingly.

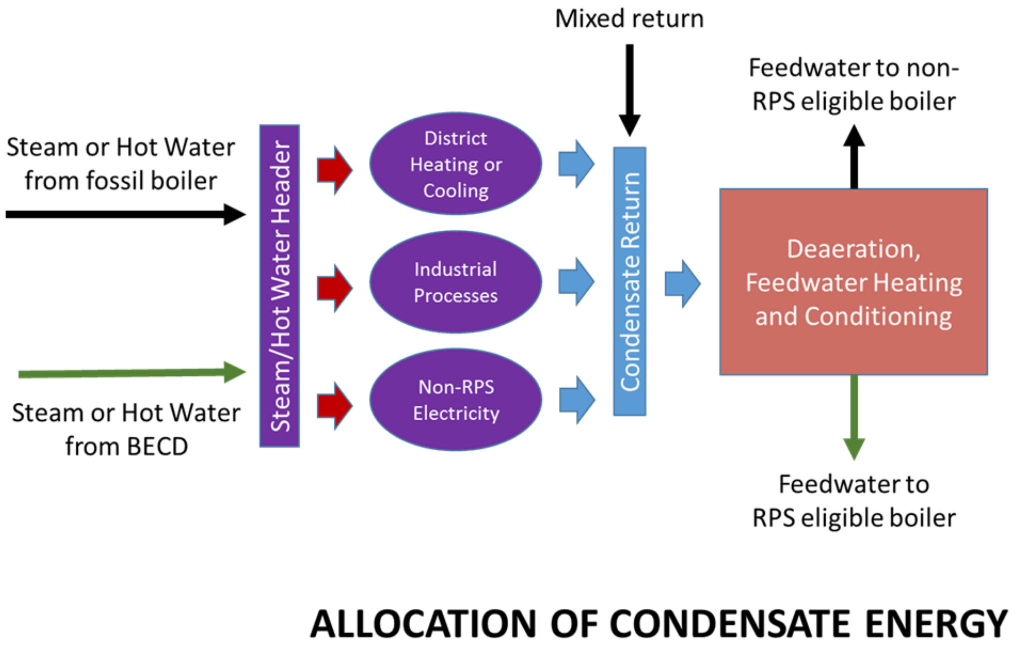
Note that this situation is also useful in conceptualizing how bottom cycles to a variety of advanced biomass energy cycles could be handled. This would include the use of waste heat boilers coupled with biodiesel fired reciprocating engines or supplementally-fired waste heat boilers coupled with gas turbines. Both of these cycles remain more in the realm of government demonstrations and are not treated here in detail, but complex cycles like these can be made to work within the framework established in this document.

8.1.4 ADJUSTMENT FOR NON-RENEWABLE ENERGY INPUTS

The most significant outside energy sources to be added to the working fluid in a system that does not include parallel operation with fossil fuel is the feedwater pumps. These pumps are most likely to be driven electrically and in many cases use grid provided electricity. However, the energy parted by the feedwater pumps on the working fluid is netted out if the metering point is downstream of these pumps as suggested previously. Note, that even in cases where the electricity is derived from on-site, renewable generation, this energy would still be considered part of the station load and is therefore netted out in the proposed metering arrangement.

The other likely source of non-renewable heat input to a thermal energy system is a fossil-fired boiler. Fossil-fired boilers are often retained (in case of a plant retrofit) or added to new installations to offer a reliable source of peaking or back-up energy to a thermal or CHP plant. This may be problematic from a renewable thermal energy standpoint depending on the manner in which the boiler has been integrated into the plant. Assuming that the metering boundaries shown in Exhibit 6 can be respected, the addition of steam from another boiler is a not an issue if one assumes that the flow of condensate energy back to the system is in proportion to the contribution provided by the respective fossil/biomass energy conversion devices. Exhibit 10 illustrates the issue schematically.

Exhibit 10: Accounting for Non-RPS Compensated Heat Inputs from Parallel Boiler



8.2 RELEVANT CURRENT AND PENDING STANDARDS

Steam metering is challenging. Typically, steam meters measure the volumetric flow of the steam and many of the attributes that make steam an attractive working fluid can also make it difficult to define flow rates accurately. Specifically, steam is a compressible fluid and its density changes with pressure and temperature. In certain temperature and pressure ranges it is also common for liquid and gaseous water to coexist to a greater or lesser extent, complicating metering. In addition, changes in a system operation or performance overtime can result in differences between design conditions for meters and the actual system pressure and temperature.

There are other challenges as well:

- Steam temperatures are often very high which impacts the accuracy and longevity of metering electronics.
- Some metering technologies use close-tolerance moving parts that can be affected by moisture or impurities in the steam.
- Poor water/steam quality can damage measurement systems and lead to inaccuracies.

In general, measuring the volumetric flow rate of steam uses the relationship between fluid velocity and area within the transport pipe. The volumetric in flow rate of a fluid in a full pipe is equal to the velocity times the cross sectional area at the measurement point. If required, the volumetric flow rate can then be converted to a mass flow rate assuming that fluid density can be measured or calculated. As noted above, for a compressible fluid density is not a constant and steam offers its own set of potential complications in real world measurement.

For this discussion of the more common steam metering techniques, it is convenient to break steam metering designs into two categories; differential pressure meters and velocity meters (FEMP 2007). However, this is not to say that this is an exhaustive list and flexibility should be provided to use other technologies.

A couple of additional points are worth addressing at this time:

1. As shown below, mass flow measurements for steam are dependent on pressure and temperature measurements. Standards and specifications must also be met to the extent that these data are required to comply with RPS metering needs.
2. In practice, proper selection, maintenance and calibration of steam metering related instrumentation is probably more important in accurately accounting for useful thermal energy than accuracy capabilities of individual meters. This means, that initial verification of metering instrumentation and regular checks are critical. Periodic third party verification and adherence to manufacturer suggested maintenance practices should be a mandatory part of any thermal metering and reporting program.

Lastly, several concepts are important to consider with respect to metering and instrumentation that are useful to define at this time:

Accuracy –Accuracy is a measurement of the difference between a measured value and that of the actual value. Published accuracies often will, and should, be referenced to specific calibration procedures including equipment-traceability to National Institute of Standards and Technology. No instrument is 100-percent accurate and manufacturers usually provide a range of accuracies in their product description and specify conditions across which the accuracy is guaranteed.

Precision/Repeatability – the precision or repeatability of a measurement describes the ability to reproduce the same value (e.g., temperature, pressure, flow rate) with multiple measurements of the same parameter, under the same conditions.

Turndown ratio – the turndown ratio refers to the flow rates over which a meter will maintain a certain accuracy and repeatability. A steam flow meter that can measure accurately from 1,000 lbs/hr to 25,000 lbs/hr has a turndown ratio of 25:1.

8.2.1 DIFFERENTIAL PRESSURE METERS

Differential pressure meters take advantage of the mathematical relationship between pressure and velocity. A physical restriction is included in the instrumentation which creates a pressure drop which can be measured and then used to calculate fluid velocities and flow rates. Fluid temperature measurement is also required. Two common types of differential pressure meters are the orifice plate meter and the annubar.

The orifice meter is a very commonly used meter, especially in older facilities. The orifice in the meter is specific to the expected flow range and as the fluid flows through the device, the restriction creates a pressure differential which is proportional to the fluid flow rate. A key issue with the orifice meter is that it has a relatively small turndown (range over which fluid flow can vary and the meter will read accurately) of 5:1. In other words, if fluid flow drops below 20 percent of the meter design, it will provide less accurate readings. This is an issue if it is used in situations where steam flow varies significantly over time. These meters have accuracies ranging from 0.25 to 2 percent, depending on the fluid, type of orifice, and installation.

The annubar is another common flow meter. The annubar flow meter introduces a pressure differential via a pipe that is inserted into the steam flow. Contained within this pipe are two smaller tubes with holes or ports evenly spaced along the length. Using these measured pressure values and the previously mentioned pressure-flow relationship, the flow rate is calculated. Annubar flow meters have a turndown ratio of up to 10:1 and are relatively easy to install. These meters can make measurements on pipe sizes from 2 to 100 inches to an accuracy of 2 percent.

Variable area flow meters are another differential pressure option. Both spring loaded and non-spring loaded options are available. The variable area flowmeter uses a vertical tapered bore tube and a float that is allowed to freely move in the fluid. When fluid passes through the tube, the float’s position changes in relation with the upward force of the fluid and the downward force from the float. The fluid flow rate can be calculated from the position of the float. The spring loaded variety, which can be used in any orientation and which makes it more useful in steam applications, includes a spring to provide a balancing force. The latter variety of this type of meter can offer good accuracy across turndowns as high as 100:1.

8.2.2 VELOCITY METERS

Velocity meters are different than differential pressure meters in that they take advantage of the linear relationship between fluid velocity and flow. Common velocity meters for steam flow include turbine meters and vortex shedding meters. Although accomplished differently, both types of meters measure a steam flow characteristic that is directly proportional to the fluid’s velocity. Again, with the velocity measured, volumetric and mass flow rates can be calculated provided that pressure and temperature are also known.

The turbine meter, as the name implies, uses a multi-blade turbine-like device which is placed into the steam flow path. The rotational speed of the device is related to the fluid’s velocity. Although very accurate, the fact that the device has moving parts can be an issue in some applications. Key issues in this respect are wear and damage due to impurities which can be carried in the steam which will result in inaccurate flow measurement. Turbine meters have accuracies in the range of 0.5 to 1.0 percent depending on fluid type and installation and turndown ratio of up to 10:1.

The vortex shedding meter measures flow disturbances around a stationary body positioned in the middle of the steam flow. Fluid flowing around the body will create eddies or vortices in the flow which can be measured. The creation and characteristics of these disturbances is proportional to fluid flow rate. Vortex meters have several key advantages. First they have no moving parts. Second, turndown ratios on the order of 20-40:1 can be achieved.

8.2.3 SUMMARY OF COMMON METER CAPABILITIES

The following table offers guidance on the relative accuracy of various flow meters. These are not standards, but are useful in understanding how meter selection may affect overall estimates of useful thermal output.

Exhibit 11: Flow Meter Characteristics

Meter Type	Accuracy (% actual)[10]	Turndown Ratio	Fluid Type
Vortex	<1.0%	30:1	Liquid or Gas
Magnetic	<0.5%	20:1	Liquid
Ultrasonic	<0.5%	100:1	Liquid or Gas
Coriolis	<0.5%	20:1	Liquid or Gas
Orifice Plate	<1.0%	5:1	Liquid or Gas
Spring-Variable Area	<1.0%	100:1	Liquid or Gas
Annubar	<2.0%	10:1	Liquid or Gas
Turbine	<0.5%	10:1	Liquid or Gas

8.2.4 STEAM METER SPECIFICATIONS CONSIDERATIONS

Whether metering is to be installed for operational purposes or for compliance with the thermal REC measurement protocol, the metering must be consistent with the flow and application. General best practices, which will be important for third party observation to confirm, are as follows:

- Determine generated steam characteristics (i.e., dry, wet, saturated, and the corresponding temperatures) and select a compatible meter.
- Determine expected range of steam flows and ensure that the accuracy requirements are sufficient over the entire flow range.
- Determine if the meter can be physically accommodated including understanding pipe sizing constraints and positioning requirements with respect to “straight run” lengths.
- Ensure that meter data logging and processing is consistent with plant systems (either designed or planned) and that measurement intervals are appropriate. With respect to this point, minimum data collection should occur at least hourly and preferentially every 15 minutes (or less).

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[10] Accuracy will differ depending on fluid type. The single value shown represents the maximum accuracy presented in the source documentation. Vendor claims and published figures will vary.

8.2.5 METER STANDARDS AND REQUIREMENTS

There are a variety of standards and guidelines related to the measurement of fluid (steam and hot water) flows that are relevant to this discussion. These include data on instrumentation performance, installation, calibration and maintenance. However, in general, instrumentation accuracy tolerances associated with flow meters (and in particular, steam flow meters) represent a significant hole. For informational purposes a few documents that are informative with respect to fluid flow are listed below:

- ASME MFC-2M – Measurement Uncertainty for Fluid Flow in the Closed Conduits
- ASME MFC-3M – Measurement of Fluid Flow in Pipes Using Orifice, Nozzle and Venturi
- ASME MFC-5M – Measurement of Liquid Flow in Closed Conduits Using Transit-Time Ultrasonic Flow Meters
- ASME MFC-6M – Measurement of Fluid Flow in Pipes Using Vortex Flow Meters
- ASME MFC-7M – Measurement of Gas Flow by Means of Critical Flow Venturi Nozzles
- ASME MFC-11M – Measurement of Fluid Flow by Means of Coriolis Mass Flow Meters
- ASME MFC-14M – Measurement of Fluid Flows Using Small Bore Precision Orifice Meters
- ASME MFC-16M – Measurement of Fluid Flow in Closed Conduit by Means of Electromagnetic Flow Meter
- PIP PCEFL001 – Flow Measurement Guidelines
- API RP 551 – Process Measurement Instrumentation
- API RP 554 – Process Instrument and Control

In the cases of the other technologies evaluated in this report which employ low temperature, liquid flow systems more specific instrumentation accuracy was available and is listed. However, as noted above, application specific requirements may dictate the use of particular instrumentation for BECDs given the higher temperature and issues associated with steam use.

Therefore, to be practical, the metering equipment, installation and placement needed to accurately assess the useful thermal output of a BECD-based system should be consistent with best practices for operating and maintain the plant. It is clear from a review of the steam and hot water meters discussed in this document that flow measurement accuracies of 2 percent of actual flow are readily achievable in most situations. Likewise temperature and pressure measurements can be made with a relatively high degree of precision.

However, accurate measurement is not being sought for its own sake. Instead, the purpose for driving RPS thermal REC generators to accurate metering is to ensure that REC purchasers are getting what they paid for. Even with fairly accurate instrumentation, there will always be some degree of uncertainty in the measured results. In truth, correcting useful thermal energy calculations for the cumulative measurement uncertainty is a more appropriate approach of protecting REC purchasers.

Given that BECD systems have the potential to require different combinations of meters and instrumentation with different capabilities; it seems more appropriate to focus on this end point rather than the individual measurements. To accomplish this, it is recommended that facilities be given the freedom to choose the meters and instruments needed to fulfill their requirements. Using this as built instrumentation data, an uncertainty analysis can be constructed which can be used as a correction factor against the useful thermal heat output of the system to ensure that this calculation does not overstate REC generation. Additional discussion on this approach is provided later in this report.

8.3 RECOMMENDATIONS ON IMPLEMENTATION APPROACHES

Given the prior discussion regarding plant requirements for instrumentation, the following guidance will help on the actual implementation needed to achieve the measurement objectives specified for BECDs.

8.3.1 BIOMASS HEAT ONLY / NON-RPS ELECTRIC GENERATION

The following instrumentation will generally be required:

- Steam conditions prior to distribution header (pressure and temperature)
- Steam flow rates prior to distribution header (volumetric meter, plus density calculation)
- Feedwater flow rates (if energy supplied by grid)
- To the extent that they exist, an energy correction factors for parasitic loads downstream of the Q_{out} metering point

For the last item, the parasitic loads should be measured as a percent of the total thermal power output measured at Q_{out} during a one-time operational certification test. The parasitic loads can be measured using a combination of existing plant instrumentation and temporary instrumentations sufficient to calculate the thermal power that is returned to the BECD at a steady state using best engineering practices and principles. These data collected should be collected at least three different operating points; minimum load, mid load, and full-load.

A weighted average parasitic load figure should be calculated using available thermal load profile data representative of annual operations which should be broken into three bins also representative of min load, mid load and full-load. The weighted average Q_{par} variable will be used in all subsequent U_{th} calculations, but is subject to annual review.

In general, all the data required to calculate U_{th} should be obtained through direct measurement with the exceptions noted above. In some cases, it may be permissible to use an indirect measurement and calculation based on equipment performance data (e.g. feedwater pump flow), but this will be addressed on a case-by-case basis.

All meters and instruments shall be installed, calibrated and maintained according to OEM specifications/requirements needed to ensure OEM accuracy and repeatability claims. In addition, data logging and processing systems should be capable of collecting all needed data at least hourly U_{th}.

All data (but especially hand-written data) will be subject to quality review. Equipment performance data will be used to ensure that recorded data is consistent with expectations and not in error.

8.3.2 ADJUSTMENT FOR RPS COMPENSATED ELECTRIC GENERATION

The following instrumentation will generally be required:

- Steam conditions prior to turbine Inlet (pressure and temperature)
- Steam flow rates prior to turbine Inlet (volumetric meter, plus density calculation)
- Extracted process steam flow rate (volumetric meter, plus density calculation)
- Extracted process steam conditions (pressure and temperature)

In this case, extracted process steam refers to steam that leaves a turbine or series of turbines before being expanded to the lowest exhaust pressure. Steam flowing through a single back pressure steam turbine is not considered to have an extracted steam flow even though the exhausted steam may be used in downstream processes.

The meter and instrumentation requirements listed in Section 8.3.1 also apply.

8.3.3 ADJUSTMENT FOR WASTE HEAT RECOVERY

The waste heat recovery case is more complex from a metering standpoint as the nature of the recovery is unknowable. Assuming that the process is a direct heat recovery using the exhaust gas directly or via an air-air heat exchange, then the temperatures and flow rates of the respective flows would need to be measured. This situation would necessarily be dealt with on a case-by-case basis.

9 PRELIMINARY AND FINAL FINDINGS TO PRESENT TO STAKEHOLDERS AT MEETINGS

Deliverables: Planning matrix for stakeholder meetings; presentation of preliminary and final results at stakeholder workshops/meetings; review of stakeholder comments and incorporation of stakeholder comments into the final report submittal.

10 DRAFT/FINAL RULE LANGUAGE SUBJECT TO REVISION BY COMMISSION & STAKEHOLDERS

Deliverables: Documents outlining requested areas of feedback and review; compilation of drafts on rule language and procedures; compilation of input documents categorized by subject; and final rule language.

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12 APPENDIX A

APPENDIX A -PERFORMANCE TEST PROCEDURES

12.1 SOLAR THERMAL SYSTEMS

The methodology for determining useful energy delivered to the distribution requires measurement of the gross heat generation rate and two important "correction" factors: heat losses in thermal storage and energy consumed to pump the working fluids in the solar energy generation loop. The following measurements should all be taken and results calculated as a part of the system commissioning performance test.

12.1.1 MEASURING SOLAR LOOP GENERATION

Solar loop thermal generation will be metered continuously to provide the most basic measurement of useful heat generated by the system. The meter installed and calibrated will meet the specifications of EN 1434 published by CEN or similar standard (ASTM standard when it is released). A full day performance test is neither practical nor necessary since collector loop output will be continuously metered. The challenge is to measure the quantities needed for the correction factors so that they represent the average for system operation throughout the year. As a compromise the tests will be conducted at conditions that represent lower insolation and higher insolation conditions. It is also recommended that the performance test be conducted in the spring or fall to attempt to average collector heat losses during the year. The temperature of storage during the test should be taken into account with the low insolation test conditions taking place when with solar storage at less than 50% of daily capacity (typically in the morning) and high insolation conditions taking place when with solar storage at more than 50% daily capacity (typically in the afternoon).

Exhibit 12: Test Conditions for Insolation and Solar Storage Temperature

Insolation Conditions	Range of measured insolation (measured at the as-built collector orientation)	Solar Storage Temperature (measured at the tank drain prior to testing)
Lower Insolation Band	200 – 400 kWh/m2	Temperature at less than 50% of the storage capacity
Higher Insolation Band	600 – 800 kWh/m2	Temperature at greater than 50% of the solar storage capacity

Test standard ISO 9459 specifies that pyranometers should be calibrated with a precision pyrheliometer to an error band of plus or minus 1%. It also specifies that measurements be taken when the collector loop reaches relatively stable thermal generation conditions – temperature changing no more than 2F over a 15 minute period. The standards does not specify the accuracy of electrical measurements and it is recommended that the solar thermal test use the same accuracy prescribed for the geothermal systems testing – an error band or plus or minus 1%. Test standard ISO 9459 prescribes a full day test for the system which is longer than necessary since the thermal generation of the system will be continuously metered. Antares recommends a 30 minute period of testing following the collector loop thermal stabilization period. The test should be performed at both the higher and lower insolation test conditions.

12.1.2 THERMAL STORAGE STANDBY LOSSES

Measuring thermal losses from a well-designed thermal storage tank sheltered in a facility utility room is very difficult to accomplish in the length of time envisioned for most commissioning tests (a few hours). Errors in measuring the change in storage temperature over a short period of time would be large. The thermal storage standby loss factor (SLF) can be easily and reasonably accurately estimated from the storage tank manufacturers AHRI certification data for the Energy Factor (EF) and Recovery Efficiency (RE):

SL = 1-EF/RE

The ratings for EF and RE can be taken from the storage tanks AHRI certification documentation or can be looked up easily on the AHRI Equipment Certification website that is open to the public using make, model and capacity.

However if the alternate method of determining the standby loss coefficient is required due to lack of certification data or custom modifications made to the tank on-site then the onsite test may be conducted. Well insulated tanks will lose less than 1 degree F per hour so a test period of 8 hours is recommended for the test to obtain a reasonable degree of accuracy in measuring the loss. This will require allowing the tank to come up to set point temperature then shutting down the thermostat for a period of 24 hours during which the tank should be idle (building supply valve shut off). At the end of the 24 hour period a reasonably large sample of the water will be extracted (5% of volume capacity) and the temperature of the sample measured as it is extracted.

12.1.3 SOLAR LOOP PUMPING POWER

Measuring the solar loop pumping power is easy to perform by technician or installer. The recommended accuracy for electrical measurements (voltage and current): plus or minus 1.0%. Voltage and current readings must be made at the same time thermal energy generation is measured. Readings at the start and 10 minute intervals should be taken for both the lower and higher insolation test conditions. Calculations will be performed separately for both periods. The average of the two calculations will determine the coefficient for collector loop pumping power consumption.

12.2 GEOTHERMAL SYSTEMS

The methodology for determining useful thermal renewable energy delivered to the distribution requires measurement of the gross heat generation rate for the ground heat source and two important “correction” factors: energy consumed to pump the working fluids in the ground energy generation loop and an allocation of compressor motor energy losses to “lift” ground heat generation (or extraction) to required temperatures for heat exchange with the distribution working fluid. The following measurements should all be taken and results calculated as a part of the system commissioning performance test.

12.2.1 MEASURING GROUND LOOP GENERATION

Ground loop thermal generation will be metered continuously to provide the most basic measurement of useful heat generated by the system. The meter installed will capable of meeting the specifications of EN 1434 published by CEN or similar standard (ASTM standard when it is released). For the performance test, ISO 13256 provides guidance on the recommended time to allow the ground source heat pump to reach steady state operating conditions. "For each test, the equipment shall be operated continuously until equilibrium conditions are attained, but for not less than one hour before capacity test data are recorded. The data shall then be recorded for 30 min at 5-min intervals until seven consecutive sets of readings have been attained within the tolerances specified. The averages of these data shall be used for the calculation of the test results." Equilibrium conditions for the purposes of the performance test shall be operationally attained when the temperature difference across the ground loop remains constant. The challenge is to conduct the test and take readings that will represent the average power consumption over the range of ground heat exchange rates and the seasonal differences in those ranges. ISO 13256 provides guidance on the recommended standard conditions for the heat pump heat exchanger inlet temperatures for conducting performance tests in a controlled test environment in Exhibit 13.

Exhibit 13: Full Load Test Conditions

Mode	Ground Water Sources	Ground Loop Sources
Cooling	59 F (15 C)	77 F (25 C)
Heating	50 F (10 C)	32 F (0 C)

It would be impossible to reproduce these conditions in a single on-site test. As a compromise for purposes of the RPS program, it is recommended that the performance test be conducted during the swing season (spring or fall) rather than either of the peak demand intervals of the cooling and heating season. Actual heat pump heat exchanger inlet temperatures will be measured during the test and compared to the standard conditions prescribed above. For the test the equipment will be operated in both the heating and cooling modes for the same period of time specified above.

12.2.2 GROUND LOOP PUMPING POWER

Once the conditions for testing prescribed above are attained, measuring the ground loop pumping power during the performance test can be performed by a trained technician, installer or professional engineer. ISO 13256 provides guidance on the recommended accuracy for electrical measurements (voltage and current): plus or minus 1.0%. Voltage and current readings must be made in both the heating and cooling portions of the test.

12.2.3 COMPRESSOR MOTOR ENERGY LOSS FACTOR

On site measurement of the compressor motor efficiency (mechanical and electrical) would be very difficult. In lieu of measurement the motor efficiency factor can be obtained from Heat Pump OEM. The seasonal values of heat pump COP used to apportion the energy losses can be taken from the heat pumps documentation for Certification by AHRI (also available on the AHRI website). Using OEM data calculating these elements of correction factors should not have an appreciable impact on the overall measurement of useful thermal energy generation. ISO 13256 provides guidance on the recommended accuracy for electrical measurements (voltage and current): plus or minus 1.0%. Voltage and current readings must be made in both the heating and cooling portions of the test. Measurements of compressor motor power should be made in the same time frame as the ground loop thermal energy generation and pumping power measurements.