Key Issues for Renewable Heat in Europe

K4RES-H

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WP 2: Common RES-H Methodology

Task 2.2

Quantifying Energy Delivery of individual RES-H applications

Subtask 2.2.1

State of the art technologies for measuring energy output of individual RES-H systems

Subtask 2.2.2

Scientific Calculation of energy output as an alternative to direct measurement

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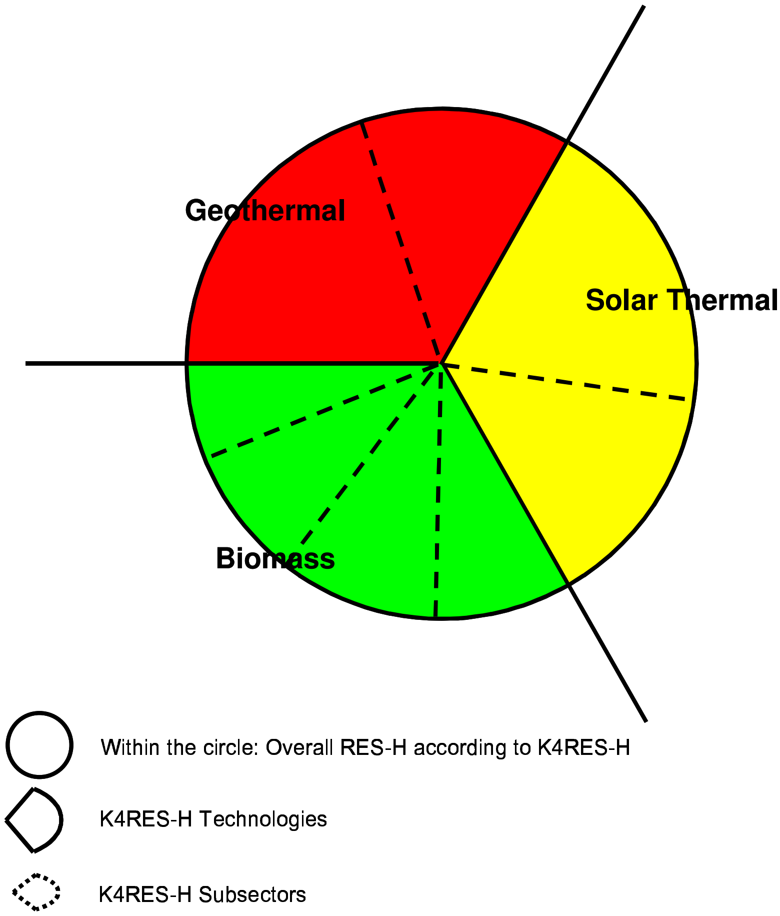
Definition for RES Production (measuring and calculating)

K4 RES- HEAT addresses the total amount of produced renewable and useful heat. This definition comprises the following specifications:

- The heat is measured directly after the conversion which means that all storage and transfer issues are neglected. Biomass is measured after the combustion, solar thermal after the collector and geothermal after the heat exchanger (direct system) or after the heat pump
- Auxiliary energy supply within the conversion process is only considered when being a considerable amount (suggestion for more than 5 %). It is expected that only Heat Pumps will find consideration as auxiliary systems.
- The energy used to produce and transport biomass shall not be considered
- For Solar Thermal the technically produced energy will find a corrective by a general assessment of the energy consumption in the specific application (e.g. one – family house)

Distinction of suitable subsectors

All three technologies – biomass, geothermal and solar thermal – have to define specific subsectors which are suitable for individual measurement and calculation methologies. These subsectors can be highlighted by the following graph:



Important specifications are given in the Annex 1 Description of the Action of the contract with the European Commission.

Task 2.2.1: State of the art technologies for measuring energy output of individual RES-H systems

Objectif: This task gives a survey of the state of the art of measuring heat delivery in larger systems, looking also at the costs and accuracy of the measuring systems.

Strategy for investigation

The study should give us a complete overview about the state of the art of measurement systems for **larger** applications in each technology sector. The survey should also include measurement systems for **smaller** applications (even if they are not commonly used).

An introduction to Heat Measurement Technologies and Principles was elaborated by JRC and is given in Annex 1.

Please give – **in a first chapter** – a general overview about heat measurement for Solar Thermal / Geothermal / Biomass technologies.

In the **second chapter** you should describe in more detail the heat measurement systems for different applications.

The description of the measurement technologies for each application should be close to existing products in the market, but avoid to mention the names of the manufacturers.

If possible, you should differ between high technologies giving very detailed and accurate measurement results and low end technologies being cost efficient. Furthermore, you should describe cutting edge technology innovation, which will come on the markets in the near future. The structure of your survey can be highlighted by the following table:

Heat Measurement in the Technology Sector Solarthermal / Geothermal / Biomass			
Typical application of the Technology Sector	High technology measurement systems	Low technology measurement systems	Cutting edge technology measurement systems
Typical applications A			
Typical applications B			
Typical applications …			

1. General Overview about Heat Measurement for Solar Thermal / Geothermal / Biomass

--- this chapter has to be completed by each European Association; 1 overview for each RES-H technology, max. 5 pages ---

Heat Measurement according to different applications

Which applications in your technology sector are typically measured? Which applications are typically not measured? Why not?

Available heat measurement systems

Which measurement system are available for different applications (independent if they are used or not)? Please list them, differentiating between high tech and low tech measurement systems. Please add innovative technologies that are expected to come to market during the next years.

Technology sector specific requirements for heat measurement

Are there any requirements for heat measurement systems in view to the particularities of your technology?

Market penetration and regional coverage

Are their any countries or regions in which measurement for certain applications are more common than in others? Please give also reasons for good or low geographical coverage.

Providers of measurement systems

Please indicate some companies, their nationality and the countries where they operate. Please also indicate in which sectors they are active (take reference to the matrix given on page 3).

Service Providers

Please indicate some companies, their nationality and the countries where they operate. Please also indicate in which sectors they are active (take reference to the matrix given on page 3).

2. Description of individual measurement systems

--- this chapter has to be completed by each European Association; about 5-10 different measurement systems; each description should not exceed 2 pages ---

Following the strategy for investigation given above please describe **each** measurement system for the different applications in accordance with the following structure.

Name of the Measurement System: ______________________________

Classification and field of application

Please describe if the measurement system is high-tech, low tech or innovative.
Briefly describe

- the applications for which the measurement technology is typically used
- the system sizes the measurement can apply to
- the range of temperatures the measurement can apply to

Technology description

Heat meters generally consist of three individual components:

1. System calculator
2. Flow measurement
3. Temperature measurement

Please refer your description to all technical details on these components. If possible use grafics and fotos.

Accuracy / Errors of measurement

A general introduction on the issue of error sources was provided by JRC and is given in Annex 2.

Technical accuracy (measurement system related)
In order to classify the technical accuracy of the measurement system please use the definitions for accuracy mentioned in the Directive 2004/22/EC on measuring instruments (see Annex 3).

class	$E = E_f + E_t + E_c$ total Error of **heat meter**	E_{min}
1		~ 2%
2		~3%
3		~4%

Example: class 2 instruments are allowed to show an total error of 3%.

[1] DIRECTIVE 2004/22/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 31 March 2004 on measuring instruments, *ANNEX MI-004* HEAT METERS

For your selected technology product, please specify the relative errors along the given criteria. If the technology doesn't reach the required values put "none" instead of the classes defined by the Directive:

class	Ef Error of Flow sensor	Et Error of Temperature sensor	Ec Error of calculator	E total error of the heat meter

Non technical accuracy and errors
Errors due to installation, dimensioning of the application or operating conditions are often more problematic than the errors on the hard-/software side of the measurement system. Example: for solar thermal the varying density of the glycol in the collector circuit has a very strong effect on the energy measured. Please describe typical errors / problems for your application.

System expenses

1. Investment for heat meters
   (e.g. investment, installation, others; please specify total costs for a basic version in Euro and costs per kW). Please indicate expenses for additional system components (e.g. M-Bus-Interface for remote reading, diagnostic and initial verification; please specify total costs in Euro and costs per kW; please compare investment for the meter to investment of RES-H system)

2. Operating costs
   (e.g. cost for measurement, technical control and revisions and monitoring services, data transmission; please specify total costs in Euro and costs per kW)

3. System life expectation
   (please name the technical life expectation of the system and the life time allowed by the administrative authorities)

3. Conclusion

--- this chapter has to be completed by each European Association; 1 conclusion for each RES-H technology, max 2 pages ---

Please summarize and evaluate the given data showing priorities and weight.

Task 2.2.2: Scientific Calculation of energy output as an alternative to direct measurement

Objectif: In smaller RES-H-systems, energy delivery is often not measured but can be calculated on the basis of scientific parameters. This task proposes sound methods to calculate the energy output of small RES-H systems.

Strategy for investigation

Please give – **in a first chapter** – a general overview about existing calculation methods for Solar Thermal / Geothermal / Biomass technologies.

In the **second chapter** please develop/select **one** calculation methodology for **each** subsector of small applications and give more details.

1. General Overview about existing Calculation Methods for Solar Thermal / Geothermal / Biomass

--- this chapter has to be completed by each European Association; 1 overview for each RES-H technology, max. 5 pages ---

Existing calculation methods

Please give a short overview about existing calculation methods for your technology (Biomass, Solar thermal, geothermal). Please also indicate in which of the defined subsectors of small applications the calculation methods are used. Who developed the calculation method and in which countries or regions are they already used?

Experiences, complexity and ability to transfer to other countries

Please summarize experiences made with the calculations methods. Comment about complexity and ability to transfer to other regions/countries.

2. Individual Calculation Methodology

--- Please develop/select <u>**one**</u> calculation methodology for <u>**each**</u> subsector of small applications, max 5 pages ---

Name of the Calculation Methodology: ___________________________

Short description of the Calculation Methodology and field of application

Please give a brief description of the calculation methodology and its principles. Briefly describe in which subsectors of small applications the calculation methodology can be applied.

Identification of typical systems within the subsector

Please identify and classify typical systems you want to handle with this calculation method (Example solar thermal systems: DHW, combisystems, thermosyphon etc.)

Input parameters / load factors

Please specify which input parameters are necessary, how these data are gathered and what you are doing if data are not available. If you develop load factors, please explain, how the load factor are defined and developed. If EN standards or prEN exists then give preference to them.

Input parameters	Are these parameters easily to gather and available?	What do you do, if data are not available?	What influence does this have on the accuracy?

Calculation procedure and output

Please indicate the formula how the energy output of the system is calculated. The result of the calculation should be the energy output of the system per year.

Accuracy of the calculation method

We suppose that measurement generally produces very good results. Some input data are measured (m^2), others are average data from the past or for a whole region, but not for the individual installation. This will directly affect the accuracy of the calculation results.
Please classify **each** parameter used to calculate the energy output:

1. very accurate (less than 5 % deviation from real output)
2. less accurate (less than 25 % deviation from real output)
3. not accurate (less than 50% deviation from real output)

Please evaluate the overall accuracy of the calculated energy output depending from the accuracy of the different input parameters.

Experiences and ability to transfer to other countries

Please specify in which countries or regions this calculation method is already used. What are the experiences? In which countries the necessary data are available? What has to be done in the other countries in order to use the calculation method?

Further steps to be done

Please specify which further steps are necessary in order to validate the calculation method.

3. Conclusion

--- this chapter has to be completed by each European Association; 1 conclusion for each RES-H technology, max 2 pages ---

Please summarize and evaluate.

Annex 1: Introduction to Heat Measurement Technologies and Principles (by JRC)

Three technologies are considered under RES-Heat: solar thermal, geo-thermal and biomass. The applications of these technologies are mainly in the building and industrial sector and differ in the size of the plant: small solar thermal collectors for domestic hot tap water, to large geo-thermal district heating plants.

Quantification of the produced heat by a plant is in principle the measurement of a mass-flow (usually water) and a temperature difference. A second way is an empirical method. The produced heat is derived from calculation that has no metrological inputs.

Heat counters, from the smallest domestic appliances to the largest industrial equipment with far more than 10 MWatt ratings, consist of three basic parts:
1. Flow meter (water is used almost exclusively as heat transfer medium)
2. Temperature sensors (usually two parts to measure a temperature difference)
3. Processor (often also called integrator)

An overview of measurement principle could be given. An initial attempt is given below.

Transit Time Meter Basic Theory
Measurements are made by sending bursts of signals through a pipe . The measurement of flow is based on the principle that sound waves travelling in the direction of flow of the fluid require less time than when travelling in the opposite direction. At zero velocity , the transit time or delta T is zero. If we know the diameter of the pipe , the pipe wall thickness and the pipe wall material the angle of refraction can be calculated automatically and we will know how far apart to space our transducers.
The difference in transit times of the ultrasonic signals is an indication for the flow rate of the fluid. Since ultrasonic signals can also penetrate solid materials, the transducers can be mounted onto the outside of the pipe. Fast Digital Signal Processors and signal analysis guarantee reliable measuring results even under difficult conditions where previously ultrasonic flowmeters have failed.

Doppler Flowmeter Basic Theory
Doppler ultrasonic flowmeters operate on the Doppler shift principal , whereby the transmitted frequency is altered linearly by being reflected from particles and bubbles in the fluid. The net result is a frequency shift between transmitter and receiver frequencies that can be directly related to the flow velocity. If the pipe internal diameter is known, the volumetric flow rate can be calculated. Doppler meters require a minimum amount of solid particles or air in the line to achieve measurements.

Thermal Mass Flow Meters
are based on an operational principle that states that the rate of heat absorbed by a flow stream is directly proportional to its mass flow. As molecules of a moving gas/liquid come into contact with a heat source, they absorb heat and thereby cool the source. At increased flow rates, more molecules come into contact with the heat source, absorbing even more heat. The amount of heat dissipated from the heat source in this manner is proportional to the number of molecules of a particular gas/liquid (its mass), the thermal characteristics of the gas/liquid, and its flow characteristics.

Annex 2: Sources of Error (by JRC)

A brief informative note on errors in measurement and analysis.

By definition a source of error is a limitation of a procedure or an instrument that causes an inaccuracy in the quantitative results of an experiment.

In principle one may recognize three main sources for errors related to reported results. These errors are identified by the origin of it in the overall process to assess reporting data from physical observations.

The three main sources of errors are due to:
1. The instruments and sensors applied for the measurements
2. The measurement of physical parameters itself
3. The numerical analysis of obtained results to assess a desired parameter

Concerning item 1

The **precision of a measuring instrument** is determined by the smallest unit to which it can measure. The precision is said to be the same as the smallest fractional or decimal division on the scale of the measuring instrument. Any measurement made with a measuring device is approximate. The sensors used for a specific measurement introduce a specific sensor error.
Sensors and instruments are available on the market that perform the same measurement but that can have a different accuracy or precision. A PT100 temperature sensor can have a higher precision than a thermocouple.
Note that the quality of the instruments and sensors are not related to the measurement itself. A PT100 temperature sensor can be measured in different ways (2-, 3- or 4-wires).

Concerning item 2

Systematic and random errors refer to problems associated with making measurements. All experimental uncertainty is due to either random errors or systematic errors. Random errors are statistical fluctuations (in either direction) in the measured data due to the precision limitations of the measurement device. Random errors usually result from the experimenter's inability to take the same measurement in exactly the same way to get exact the same number. Systematic errors, by contrast, are reproducible inaccuracies that are consistently in the same direction.
If you measure the same object two different times, the two measurements may not be the same. The difference between two measurements is called **a variation** in the measurements. Note that the number of samples taken by the instrument for a single sensor is important as well as is the time of the interval to take the samples that depends a lot on the physical ,process to be measured.

Systematic errors are difficult to detect and cannot be analyzed statistically, because all of the data is off in the same direction (either to high or too low). Spotting and correcting for systematic error takes a lot of care. The position of a temperature sensor for example, can be made wrong by the installer, producing data that are not representative for the phenomena that has to be measured.

Concerning item 3

The numerical analysis requires a mathematical model that by definition is an approximation of the physical process and therefore is never perfect. Furthermore the analysis is applied to convert measured data into a parameter that can not be measured directly. A good example is an energy flow. This requires the measurement of a temperature differences in a flow of fluid over a certain period of time with a certain observation interval. The obtained data have to be integrated to assess an energy flow. The errors due to this mathematical process are called **analysis errors.**

Note that some apparatus integrate all aspects of the forementioned errors. For example an energy flow meter includes the sensors to measure the physical quantities of temperature and flow and include a software tool to integrate these measured data in order to display directly a value for the energy flow.

Annex 3: Directive 2004/22/EC on measuring instruments

The maximum permissible relative errors applicable to a complete heat meter or an assembled heat meter, expressed in percent of the true value are:

The maximum permissible relative errors applicable to a complete heat meter or an assembled heat meter, expressed in percent of the true value are:

$E = E_f + E_t + E_c$

This formula can be inserted in the following table :

class	$E = E_f + E_t + E_c$ total Error of **heat meter**	E_{min}	E_{max}
1		~ 2%	10%
2		~3%	10%
3		~4%	10%

The individual calculations themselves can be highlighted in a separate table:

class	E_f Error of **Flow sensor**	E_f min $q_p=q$ upper flow level	E_f max $q_p>q$ lower flow level
1	$E_f = (1 + 0{,}01\ q_p/q)$, but not more than 5 %,	~ 1%	5%
2	$E_f = (2 + 0{,}02\ q_p/q)$, but not more than 5 %,	~2%	5%
3	$E_f = (3 + 0{,}05\ q_p/q)$, but not more than 5 %,	~3%	5%

	E_t Error of **Temperature sensor**	E_t min if ΔT min<<ΔT	E_t max if ΔT min=ΔT
No classes	$E_t = (0{,}5 + 3 \cdot \Delta T\ min/\Delta T)$	~ 0,5 %	3,5%

	E_c Error of **calculator**	E_c min if ΔT min<<ΔT	E_c max if ΔT min=ΔT
No classes	$E_c = (0{,}5 + \Delta T\ min/\Delta T)$	~ 0,5 %	1,5%

q = the flow rate of the heat conveying liquid;
q_p = the highest value of q that is permitted permanently for the heat meter to function correctly;
ΔT = the temperature difference $T_{in} - T_{out}$ with ΔT ‡ 0;
ΔT_{min} = the lower limit of ΔT for the heat meter to function correctly within the MPEs;