:metabolon – Measuring Flow and Temperature on the heating network

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Abstract

This paper presents a series of flow and temperature measurements on the principal heat network of :metabolon in Lindlar, Germany. These measurements intend to show the behaviour of the system on specific production areas of :metabolon for future monitoring and optimisation purposes. Such measurements allow the analysis of the system's heat flow through the network, which showed that losses exist, some areas. The results demonstrate successfully that the temperature and flow changes deserve more detailed and fixed monitoring in specific areas to help the user decide the optimum measuring point.

6 Introduction

Nowadays, heating networks are a very important source of heat transfer in communities. Different mediums are used to produce this heat with different efficiency levels. During the transfer process, ambient temperature and humidity may cause notable losses on the system.

The following paper focuses on providing the results of a series of temperature and volumetric flow measurements on a heating network, using two modern mobile ultrasonic devices, made in one week with a weekend included in the middle during the beginning of the cold season in Germany. The results shall provide an overview of the

heat demand and losses on the system, to introduce various fixed measuring instruments for monitoring and preventive purposes.
First a brief introduction to the :metabolon site is presented to the reader, where the different areas of the site, the heating network and the medium used to transfer the heat on the whole system are introduced. The measurements will be described on section 3 with a detailed explanation of the schedule and different areas being measured. Linked to section 2, in section 4 the physical properties of the medium used to transfer the heat trough the pipes on the network is explained, with the presentation of two linear models to obtain more accurate results when converting from volumetric to heat flow.
Section 5 will focus on the flow meters used for these measurements, the ultrasonic technology behind them and the installation requirements to perform better measurements. To finish the paper, Section 6 presents the plots of the performed measurements during the specified time period with a brief discussion.

2 :metabolon site

Located almost 43 km to the east of Cologne, in Lindlar, Germany. Before 2004, :metabolon was used as a garbage and waste deposit for the surrounding cities. Figure 1 shows a map with the location of :metabolon site. Today, it is still used as a garbage collection plant to process it and produce compost for the farmers of the region. Taking advantage of the site's location, :metabolon is used as a research facility to improve and develop the waste-to-energy process as well as to introduce the area as a family park to the surrounding communities and show them the necessities, advantages of recycling and management of waste. This will play an important role on future generations for it will mean that more investment and interest on research and development will improve the process.

Figure 1: Location of :metabolon site represented by the orange triangle.

:metabolon consists in different areas as follows, listed in english and [german]:

1. Transfer centre [Transferzentrum]
2. Office building [Verwaltungsgebäude]
3. Research building [Forschungsgebäude]
4. Old workshop [Alte Werkstatt]
5. Sorting plant [Sortieranlage]
6. Fermenting and Composting Plant [Vergärungs- und Kompostierungsanlage (VKL)]
7. Sanitation [Hygienisierung]
8. Transfer centre for special wastes (TCSW) [Sonderabfall Zwischenlager]
9. Wood drying system at the Biomass farm [Holztrocknung beim Biomassehof]
10. New workshop [Neue Werkstatt]
11. Combined heat and power plant (CHP) [Blockheizkraftwerk (BHKW)]

The items from 1 through 3 are offices and buildings used for administrative purposes. The rest are working areas for the different processes of the :metabolon site.

2.1 Sample and inoculum preparation

About 2 kg of 95 % air-dried SG produced from the non-alcoholic fermentation of a mixture. The main source of heat comes from the CHP plant provided by a third supplier, where :metabolon pays a monthly/yearly fee for their energy consumption. There are three CHP's available on the system, which, depending on the heat demand, they are started as needed. Each CHP provides the network with 600 kW of heat, making a total of 1800 kW when all of the three are working. Because the network size is too long, the heating system itself encounters some troubles supplying enough heat to the buildings enlisted from 1 to 4. Thus a secondary network, which source is located in the basement of the "alte Werkstatt", has been installed to supply the requirements of these areas. This secondary network is supplied by an oven that burns wood chips to produce heat, which, in combination with a heat exchanger, is then used to heat water. Figure 2 shows the organisational chart of the heating network in :metabolon, where the main network is represented by the continuous line (purple) and the secondary connections by the dashed line (orange).

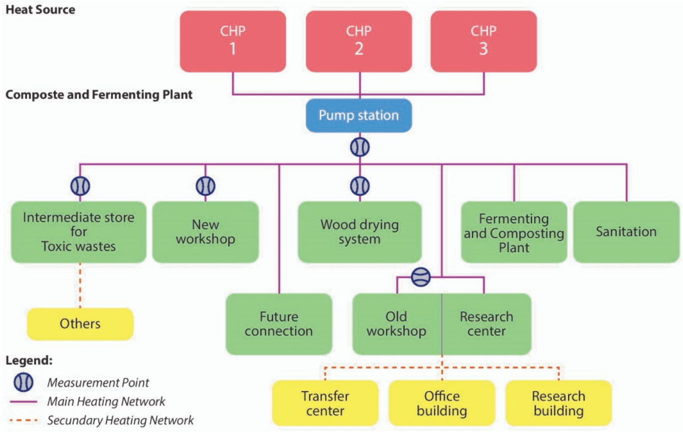


Figure 2: Organisational chart of the heating network at :metabolon.

There are two different mediums used on the network to transfer the heat. First there is Water (H_2O) as principal medium and, second, there is a mixture of different percentages of Monoethylene Glycol ($C_2H_4(OH)_2$), whose mixture depends on the outside temperatures. The mixture available on the system during the measurements was around 80 % Water and 20 % Glycol.

3 Measurements

Using 2 loaned mobile ultrasonic meters, introduced in Section 5, to measure the system, first a limited amount of areas were selected to obtain the most information of the system. The measurements took place 07.12.2012 – 12.12.2012 and the proposed areas to observe were:

1. Old workshop
2. Transfer centre for special wastes (TCSW)
3. Wood drying system
4. New workshop
5. Combined heat and power plant (CHP)

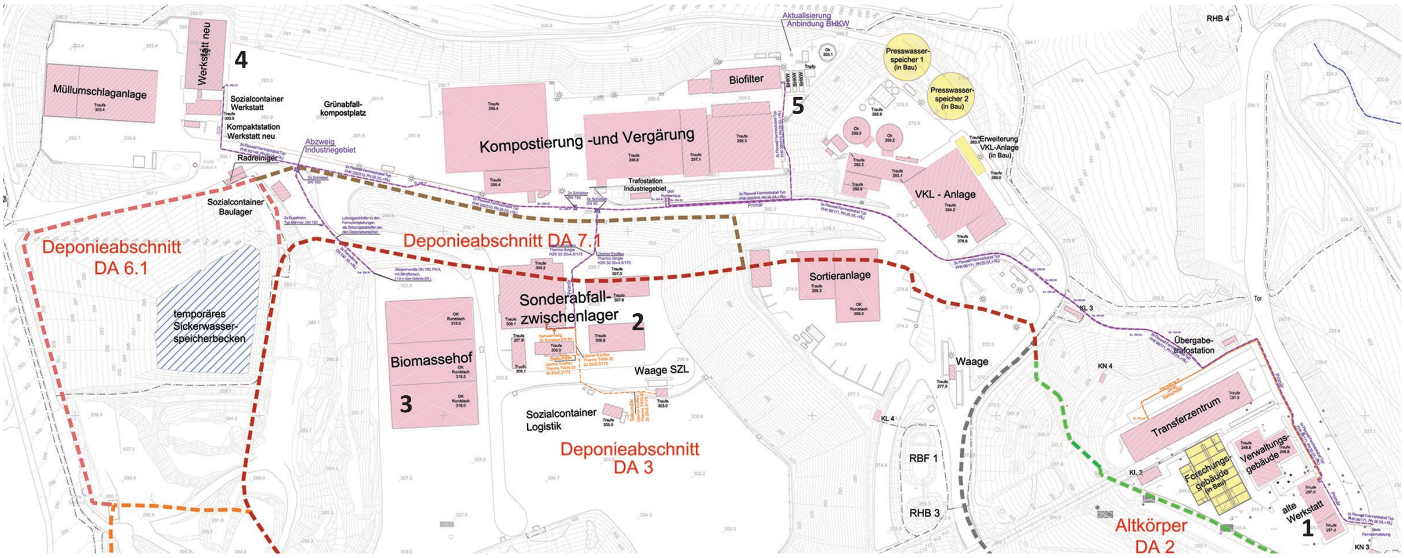


Figure 3: Details of the main areas of :metabolon site.

Point number 5 (CHP) was selected because it is the main source of heat on the system. Because :metabolon site is not flat, the different heights cause some losses on the system, thus the other four points were selected because of its distribution of heights on the system. Figure 2 shows as well the selected measuring points for this task represented by the flowmeter symbol in a circle.

Two flowmeter were selected so the system can be measured from heat source, CHPs, to the other areas shown in Figure 2.

For this reason, one flow meter (flow meter 1) shall always measure the CHP's to use it as a reference point. The other areas shall be measured with flow meter 2 in tacts of 30 minutes approximately. During nights and the available weekend, flow meter 2 stayed at the "Old Workshop" to measure the behaviour of the system on the initial day of the week, Monday (10.12.2012).

3.1 Considerations on the different areas

The weather conditions at the time of the measurements play an important role on the use of the heating network, which defines if the system was being used or not. Figure 4 shows the hourly average behaviour of the temperatures during the period of the measurements.

Old Workshop

In the old workshop, the measurements took place in the basement of the building, where the main heating network is connected to the child network through a heat exchanger. In this case it is important to mention that the system on this area is equipped with a special weather temperature control, which is being used to control the supply flow on the child network by using weather information.

Transfer Centre for special wastes

In the transfer centre for special wastes, the measurements took place at the roof of the building. This area is the highest point in the whole heating network. It is well known that sometimes it presents problems with the heating system because of the height and installation of the system. The system consist in a heat exchanger with an small expansion tank, which is being used to protect the heating water system from high pressures on the main stream.

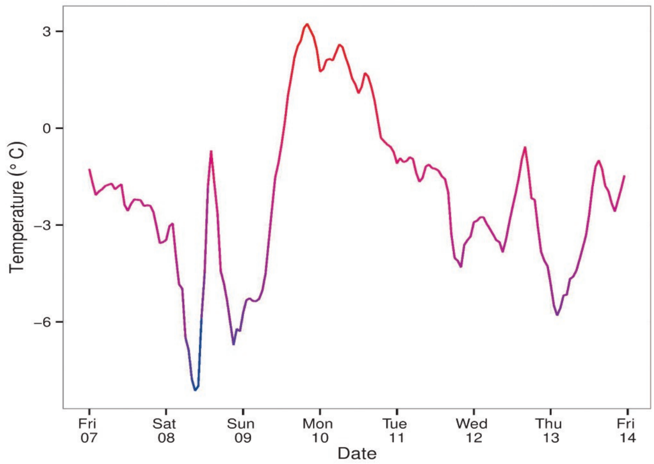


Figure 4: Hourly averaged temperatures in ˚C at :metabolon during the measurements from Friday 7 to Friday 14 of December 2012.

Wood drying system

At the wood chips drying system, the measurements took place outside. This system is coupled with an hydraulic separator to join the main and the child network systems which maintains a constant low pressure and avoids variability.

Combined heat and power plant

At the CHP's, the measurements took place at the beginning of the main heating network after the main heat exchanger. This is the main heat source, as mentioned before. Before the heat exchanger, that connects the CHP's and the main heating network, an approximate total volume of medium on the line of 5.000 l is considered and after the heat exchanger a total volume of 26.000 l.

Considerations for the measurements

Since the measurements shall be done on different areas, ultrasonic flow meters need some information before the measurement could be done.

Table 1 shows the pipe properties for each measured area, taken in consideration for the configuration of the flow meters. Since the pipes were almost new, a roughness of 1 mm and no lining was considered for every pipe place on the first floor. The system is almost new and has a simple flow control system.

Table 1: Pipe configuration for every area. Used to configure the mobile sensors.

Area	Out. Diam (mm)	Wall Thick (mm)
CHP	108.00	2.00
Old Workshop	89.00	2.00
TCSW	42.00	1.50
New Workshop	42.00	1.00
Wood drying	76.00	2.00

4 Heating medium

On the previous section it was mentioned that the heating network contains a mixture of Water (H_2O) and Mono-ethylene Glycol ($C_2H_4(OH)_2$). This mixture depends on the freezing point, which is needed for the system to support lowest temperatures. For this reason it is determined that an approximate mixture of 80 % Water and 20 % Glycol was being used during the time of the measurements to support temperatures of −10 °C. Figure 5 shows the density (kg/m^3) relation to temperature (°K) of the solution Water-Glycol at different percentages of Glycol, whereas Figure 6 shows the Specific Heat (kJ/kg °K) in relation to temperature (°K) of the different percentage solutions of Glycol in Water (Table Dd 21 from VDI Wärmeatlas) (Sun & Teja 2003). These plots will be used to convert the measured volumetric flow to heat flow rate on the system.

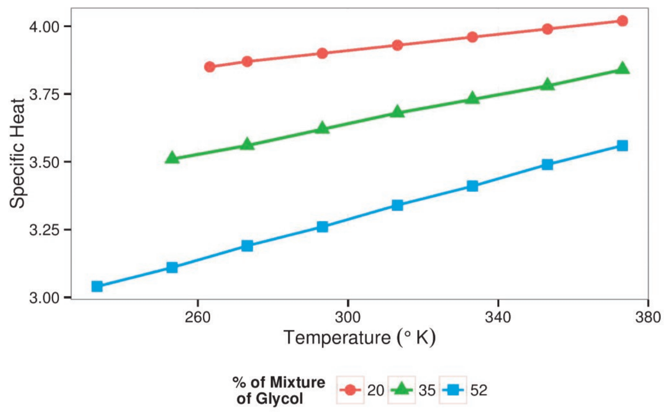


Figure 6: Specific Heats kJ/kg °K of Glycol at different temperatures in °K and percentage of solution with Water. The different levels of solution are 20 %, 35 % and 52 % of Glycol with water.

To use the relation of densities and heat from Figures 5 and 6 a linear model of this data must be built, and since the system uses only 20 % mixture of Glycol and 80 % of water, the red lines with dots from the figures are selected for the proposed regression models.

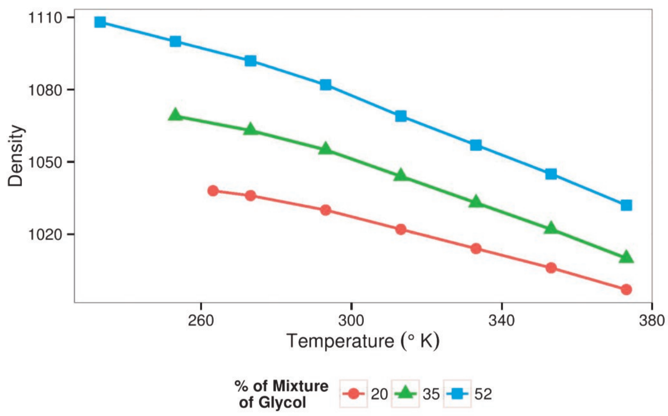


Figure 5: Densities in kg/m^3 of Glycol at different temperatures in °K and percentage of solution with Water. The different levels of solution are 20 %, 35 % and 52 % of Glycol with water.

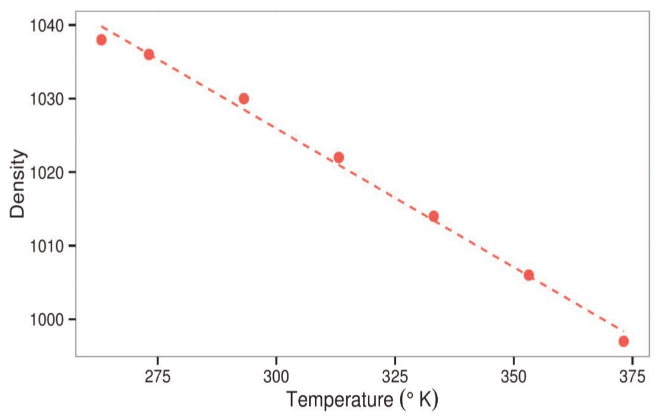


Figure 7: Linear model for the density properties ρ in kg/m^3 of a mixture of 20 % Glycol and 80 % of water with an accuracy of 99,994 %, represented in Figure 5. The dots are the real values and the dashed line represents the linear model.

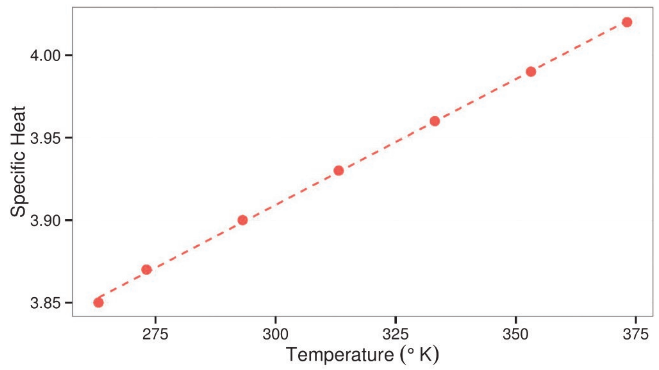


Figure 8: Linear model for the specific heat properties c_p in kJ/kg °K of a mixture of 20 % Glycol and 80 % of water with an accuracy of 99,999 %, represented in Figure 6. The dots are the real values and the dashed line represents the linear model.

4.1 Volumetric to heat flow rate

Since the obtained measurements were temperature and volumetric flow, to obtain heat flow rate, a conversion is needed using the heat flow relation (Cengel, Y. A. & Boles, M. A.).

$$q = \frac{Q}{c_p \times \Delta T \times \Delta p'} \tag{1}$$

Where *q* is the volumetric flow in $\frac{m^3}{h}$, Q is the heat flow rate in kW, c_p is the specific heat capacity in $\frac{kJ}{kg^{\circ}K}$ and ρ the density in $\frac{kg}{m^3}$. Notice that equation 1 is in m^3, for the measurements are in l, thus to convert to the International System of Units the relation.

$$q = 1\frac{l}{h} = \frac{1}{1000}\frac{m^3}{h} \tag{2}$$

can be used to obtain the desired volumetric flow. From (1) it is obtained heat flow rate in $\frac{kJ}{h}$, for 1 $\frac{kJ}{s}$ is equal to 1 kW, thus

$$Q = 1\frac{kJ}{h} = \frac{1}{3600}kW \tag{3}$$

is used to obtain heat flow rate in kW. To use the densities and specific heats at different temperatures from the relations of Figure 5 and Figure 6 for the mixture of 20 % Glycol (red lines and circle points), their respective linear model have to be obtained as

$$p = -0.3771955 \times T + 1139.086 \tag{4}$$

$$c_p = 0.001525496 \times T + 3.45154 \tag{5}$$

Both linear models are represented in Figure 7 and Figure 8. Once the respective conversions and linear models are obtained, equations 2 and 3 are substituted in equation (1) to get the final conversion to heat flow rate from volumetric flow

$$Q = \frac{q \times c_p \times (\Delta T) \times p}{3600000} \tag{6}$$

5 Equipment

The measuring devices used for the task, are two mobile ultrasonic flow meters with temperature option. To understand in detail how these devices are used to measure, an overview to the basic idea of the ultrasonic technology and the cares one must consider on the installation of the devices to achieve an accurate measurement is introduced.

5.1 Ultrasonic theory

There are two main types of ultrasonic flow meters: Transit-time and Doppler reflection.
Transit-time flow meters are designed for clean fluids and Doppler reflection type for dirty, slurry-type streams. The sensor that was used in this article is a transit-time flow meter.

Transit-time flow meters
A transit-time flow meter measures flow by measuring the time taken for an ultrasonic energy pulse to traverse a pipe section, both with and against the flow of the liquid within the pipe [2] [6]. The time t_{AB} for the ultrasonic energy to go from transducer *A* to transducer B is given by the expression

$$t_{AB} = \frac{L}{C + V_{\cos\varphi}} \tag{7}$$

and the time t_{BA} to go from B to A is given by

$$t_{AB} = \frac{L}{C - V_{\cos\varphi}} \tag{8}$$

where C is the speed of sound in the medium, L

the acoustic path length in the medium, φ is the angle of the path with respect to the pipe axis. By combining terms and simplifying it can be shown that for $V \ll C$,

$$\Delta t = t_{BA} - t_{AB} = 2LV\frac{\cos\varphi}{C} \quad (9)$$

Also giving us

$$V = L\frac{\Delta t}{2}\cos\varphi_A^2 = K\frac{\Delta t}{t_A^2} \quad (10)$$

where t_A is the average transit time between the transducers. Since the cross-sectional area of the pipe section is known, the product of area and velocity will yield volumetric flow rate.

5.2 Installation cares

The correct selection of the measuring point is crucial for getting reliable measurements results and a high measurement accuracy.

A measurement on a pipe is possible if:

- the ultrasound propagates with sufficient high amplitude (acoustic penetration),
- the flow profile is fully developed (undisturbed flow profile), which will be discussed on paragraphs acoustic penetration and undisturbed flow profile.

The correct selection of the measuring point and the correct positioning of the transducers is influenced by:

* Diameter, material, lining, wall thickness and form of the pipe,
* the medium, and
* gas bubbles in the medium.

Avoid measuring points in the vicinity of deformations and defects of the pipe and in the vicinity of welds. This is because near deformations the liquid can became turbulent and therefore generate bubbles. Also avoid locations with deposit formation in the pipe [FLEXIM GmbH: User Manual].

Acoustic penetration

The acoustic penetration is reached when pipe and medium do not attenuate the sound signal so strongly that it is completely absorbed before reaching the second transducer. The attenuation in the pipe and in the medium depends on:

- kinematic viscosity of the medium,
- proportion of gas bubbles and solids medium,
- deposits on the inner pipe wall, and
- pipe material.

The following requirements must be fulfilled at the measuring point:

- the pipe is always filled completely,
- no material deposits in the pipe, and
- no bubbles accumulate.

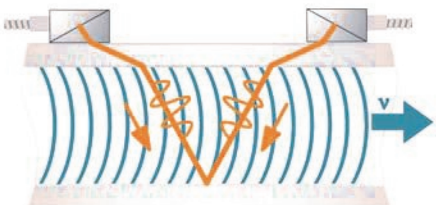
Undisturbed flow profile

Some flow elements (elbows, slide valves, valves, control valves, pumps, reducers, diffusers, etc.) distort the flow profile in their vicinity. A careful selection of the measuring point helps to reduce the impact of disturbance sources. It is important that the measuring point is chosen at a sufficient distance from any disturbance sources. Only then it can be assumed that the flow profile in the pipe is fully developed. However, measuring results can be obtained even if the recommended disturbance sources cannot be observed for practical reasons.

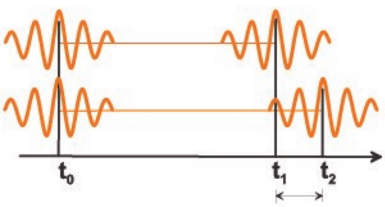
5.3 The Equipment

The Fluxus F601 sensor is a portable instrument for non-invasive, quick ultrasonic flow measurement with clamp-on technology for all type of piping. The Fluxus has an integrated data logger with a serial interface and a Li-Ion battery that provides 14 hours of measurement operation. The Fluxus F601 can work in outsides and in a lot of environments thus its water and dust-tight (IP65); resistant against oil, many liquids and dirt (Figure 9) [FLEXIM GmbH: User Manual]. Sometimes the gaseous or solid content in the medium increase occasionally during measurement, a measurement with the transit time difference principle is no longer possible. Noise Trek is a feature integrated in this sensor that will be selected by the flow meter. This measurement method allows the flow meter to achieve a stable measurement even with high gaseous or solid content [FLEXIM GmbH: User Manual].

Figure 9: Front and connections views of the Flow meter Fluxus F601 used for the measurements.



a) Path of ultrasonic signal.



b) Transit time difference Δt.

Figure 10: Representation of the ultrasonic path and the transit time.

The Fluxus sensor measures the flow of the medium by ultrasonic signals using the transit-time difference method as measurement principle.

A pipe line has two transducers installed, one in front of another (Figure 10 a) transducer emits signals that [1] [2] [3] [4] [5] [6] [7] [8] t are reflected to the opposite side and finally received by the second transducer. It is important to mention that the signals are emitted alternatively and against the flow direction. As the medium in which the signals propagate is flowing, their transit time in flow direction is shorter than against the flow direction (Figure 10b) [FLEXIM GmbH: User Manual].

The difference between transit times (Δt) is measured allowing to determine the average flow velocity on the propagation path of the ultrasonic signals [FLEXIM GmbH: User Manual]. A flow profile correction is then performed to obtain the area average of the flow velocity, which is proportional to the volumetric flow rate. In the Fluxus the volumetric flow rate is calculated by

$$V = k_{Re} A k_a \frac{\Delta t}{2 t_{fl}} \qquad (11)$$

Where V is the volumetric flow, k_{Re} is the fluid mechanics calibration factor, A the cross-sectional pipe area, k_a acoustical calibration factor, Δt transit time difference and t_{fl} transit time in the medium.

The setting up of all the parameters needs for making the measurements are simplified in a quick-start-up guide that is provided with the sensor or also available on-line.

6 Results

The following section will show the measurements taken from the period mentioned in Section 3. For space reasons and demonstration purposes, only those who presented a special behaviour and measures during the weekend are going to be shown.

Combined heat and power plant (CHP)

Figure 12 shows the complete set of measurements from 07.12.2012 – 11.12.2012, 11:17 time gathered from the CHP's. A common pattern between the volumetric flow (Figure 12b) and the supply temperature (Figure 12a) can be observed. Notice, that at around 02:00 o'clock on Sunday morning (09.12.2012), the supply temperature reaches at some points the same value as the return temperature.

Old workshop

Figures 13a and 13c show the measurements of the "Old workshop" in the time window from 07.12.2012 15:24 to 10.12.2012 9:22 o'clock in the morning. Notice from Figure 13a that the same behaviour of the supply and return temperatures is shown as in Figure 12a at the same time, 02:00 o'clock on Sunday morning (12.12.2012) but Figure 13b shows a different tendency than the one shown in Figure 12b, where instead of showing a decreasing flow related with the temperature behaviour, it increases.

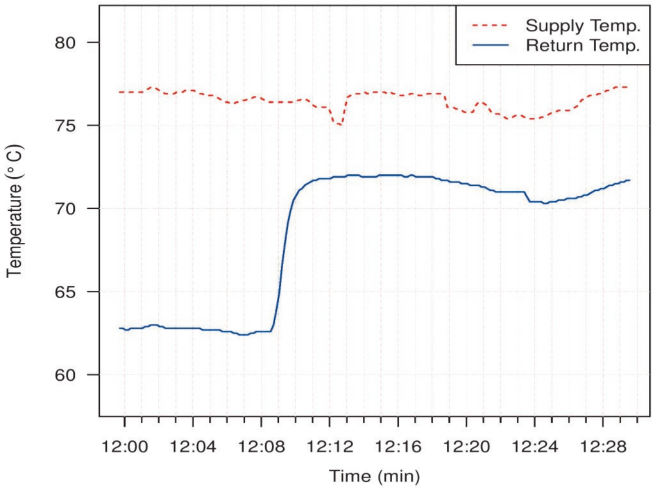
Wood drying system

Figure 11 shows the measurements taken at the "Wood drying system" on Monday 10.12.2012 from 11:59 to 12:29 clock, where at around 12:09 o'clock the heat flow rate went down almost 100kW, because the return temperature rose to almost 73 °C, reaching almost the supply temperature of 77 °C.

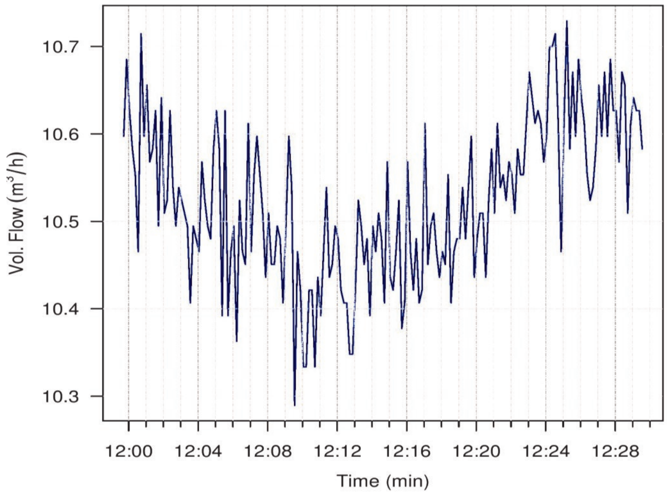
Transfer centre for special wastes

In Figure 14 are the measurements shown which we have taken at the "Transfer centre for special wastes" on Monday 10.12.2012 from 11:03 to 11:35 clock.

Notice that during this small period of time, the flow and the temperatures decay slowly. At this period of time, this behaviour is shown in the whole system, which origin comes from the heat source.



(a) Supply (dashed line) and Return (solid line) temperatures (°C) of the "Wood drying system".



(b) Volumetric Flow ($\frac{m^3}{h}$) of the "Wood drying system".

(c) Heat Flow (kW) of the "Wood drying system".

Figure 11: The plots show the measurements made at the "Wood drying system" in the time window from 11:59 to 12:29 clock, 10.12.2012. From top to bottom, the first plot shows the Supply and Return temperatures in °C, the second plot shows the volumetric flow in $\frac{m^3}{h}$ and the third plot shows the heat flow rate in kilowatt.

New workshop

Figure 15 show the measurements taken at the "New workshop" on Tuesday 11.12.2012 from 11:49 to 12:20 clock. It can be said that, at that time window, there was a stable temperature tendency of the system, but the volumetric flow changes almost 0.6 $\frac{m^3}{h}$.

7 Discussion

Combined heat and power plant (CHP)

The measurements on the CHP's showed that the temperature on the supply side reached sometimes the temperature on the return side.

Considering that the supply volume is around 5.000 l and that on the main network a volume of 26.000 l is flowing through the system, when the flow decreased, the supply temperature decreased as well, followed by the return temperature on a delay of 2 hours, which is to be expected because of the volume difference. More volume takes longer to reach the same temperature of the mediums as less volume.

The reason for such flow decays comes from the seasonal tendency of the system, i.e. the work schedule and lunch times, causing the system to pressure and lower the flow. Notice as well that, by observing the heat flow, the system sometimes had no heat transfer at all and that around 07:00 o'clock in the morning the system reached again an optimum operating point.

Old workshop

The old workshop has a control system based on the weather conditions which controls flow. The measurements show that indeed to maintain the temperature the flow reacted as it should without any problems. From the weather conditions shown in Figure 4, it is noticed that on the exact same time periods where the temperatures decreased, an inverted tendency of flow is shown in Figure 13b, this is because of the flow control system based on the weather conditions.

Wood drying system

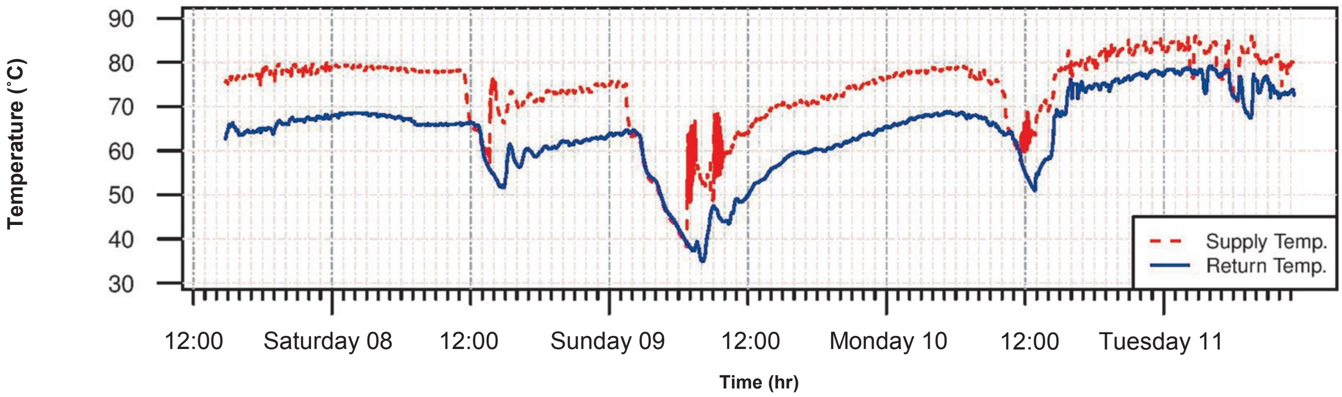
The wood chips drying system showed a very simple behaviour, when the return temperature increased, the drying system was turned off. The peculiar observation for this system is that neither the supply temperature nor the flow changed much, since the system is coupled with a hydraulic separator. The system could be optimised by installing a valve to open or close whenever the drying system is running or not, respectively. This will avoid the main system to loose heat during these shut-offs, for once it restarts, the system shall regain the lost heat to obtain the desired temperature.

Transfer centre for special wastes

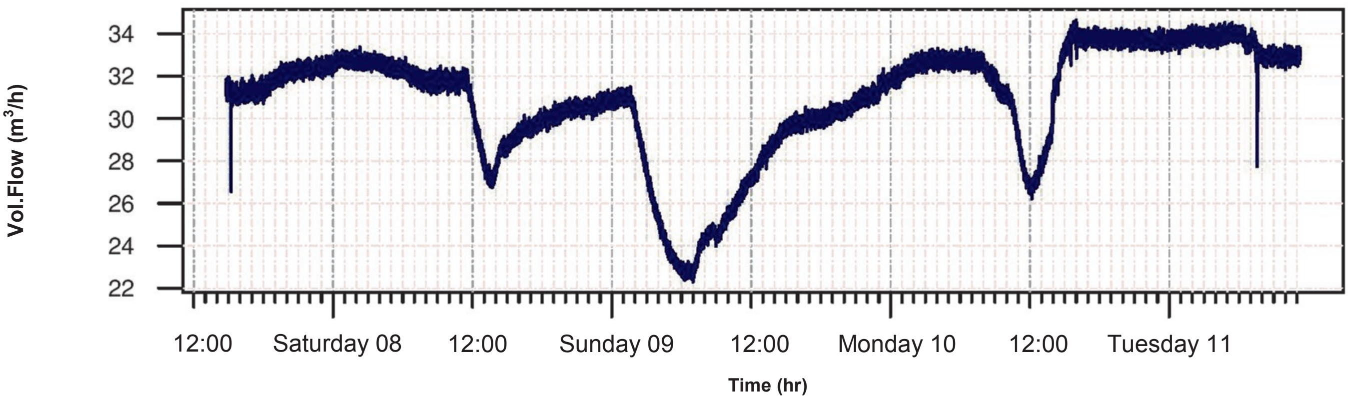
Since the transfer centre for special wastes is located on the highest point in :metabolon, it is sometimes difficult for the system to reach such point, and besides that, the use of an expansion tank to protect the system from high pressures, does not allow sometimes the medium to reach there. Because the temperature differences vary between 0°C and 40°C and since, the higher the temperature difference, the higher the pressure on the line, the small expansion tank avoids, that this high pressures, the medium to reach the sub-system at this point. A higher expansion tank can help avoid this problem, but further investigation shall be done to avoid the wrong expansion tank.

New workshop

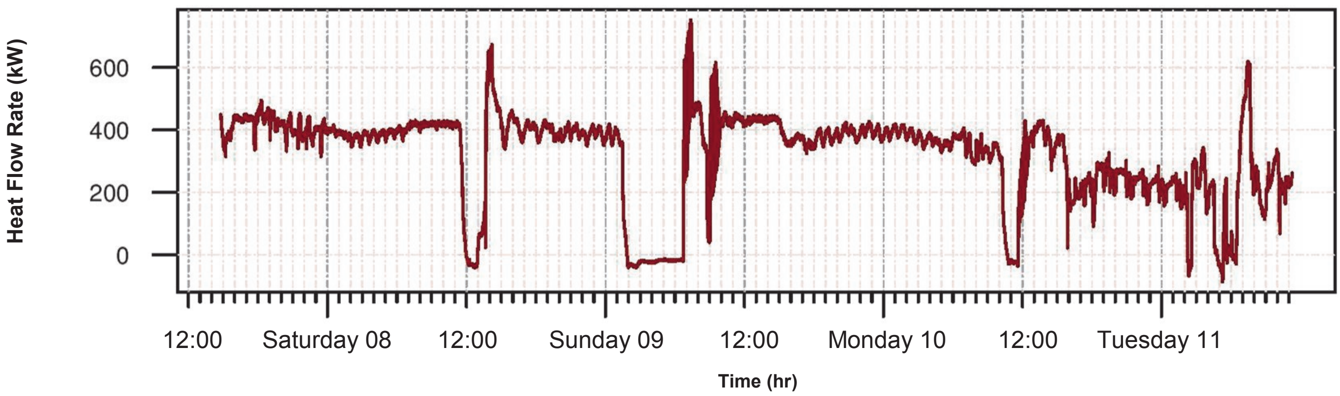
The new workshop did not presented any special characteristics since it is shown that a flow control is managing the fluctuations of the system, keeping the temperatures stable.



(a) Supply (dashed line) and Return (solid line) temperatures (˚C) of the CHP's.

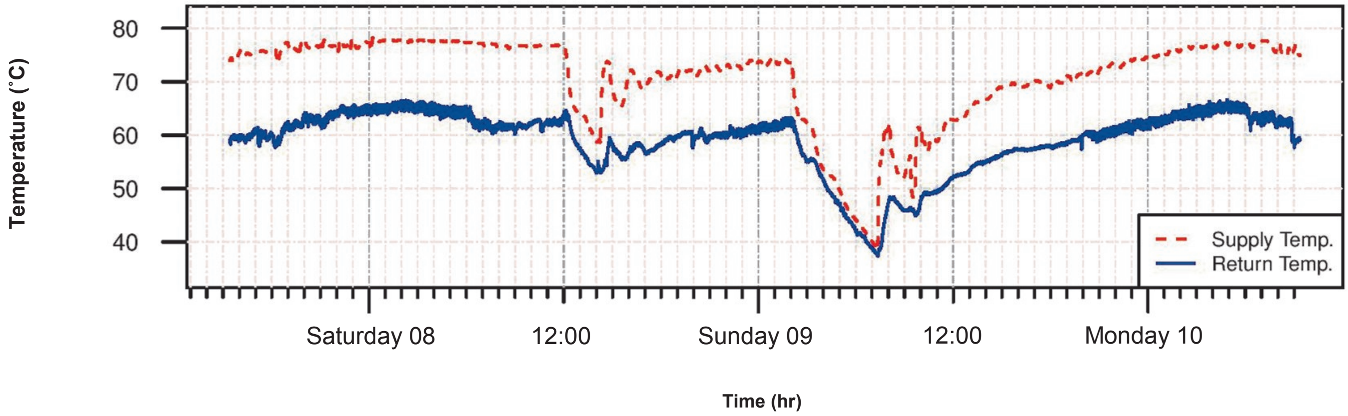


(b) Volumetric Flow ($\frac{m^3}{h}$) of the CHP's.

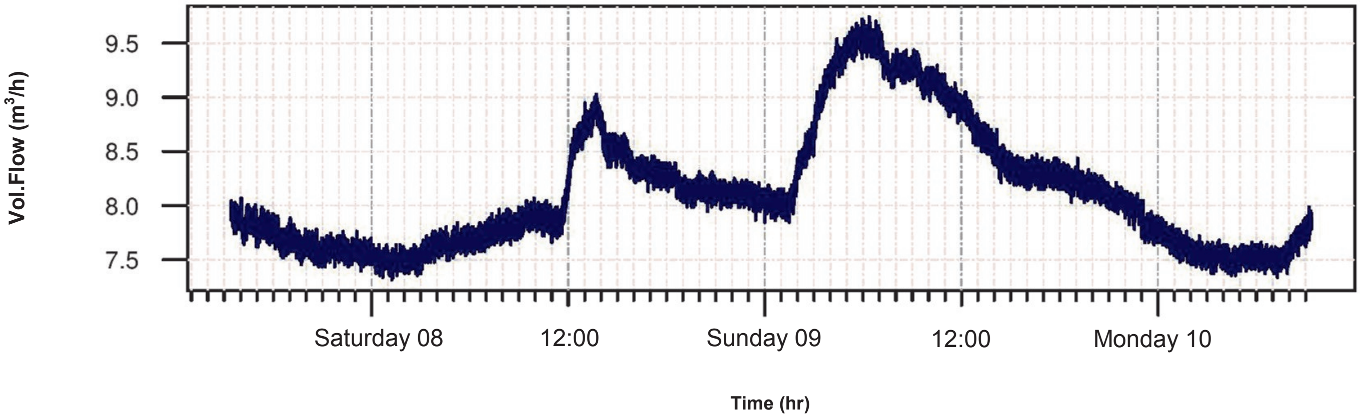


(c) Heat Flow (kW) of the CHP's.

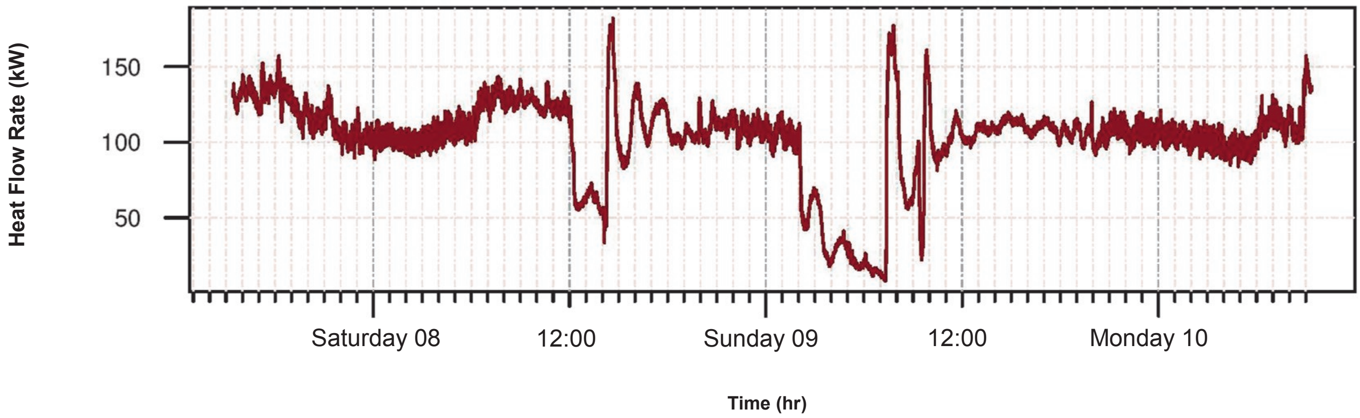
Figure 12: The plots show the measurements made at the CHP's in the time window from 07.12.2012 to 11.12.2012, where the major ticks mark the start of a day (00:00 hours), the minor ticks are separated by one hour and the middle ticks represent the noon (12:00 hours) of the corresponding day. From top to bottom, the first plot shows the Supply and Return temperature in °C, the second plot shows the volumetric flow in $\frac{m^3}{h}$ and the last the heat flow rate in kilowatt (kW).



(a) Supply (dashed line) and Return (solid line) temperatures (°C) of the "Old workshop".

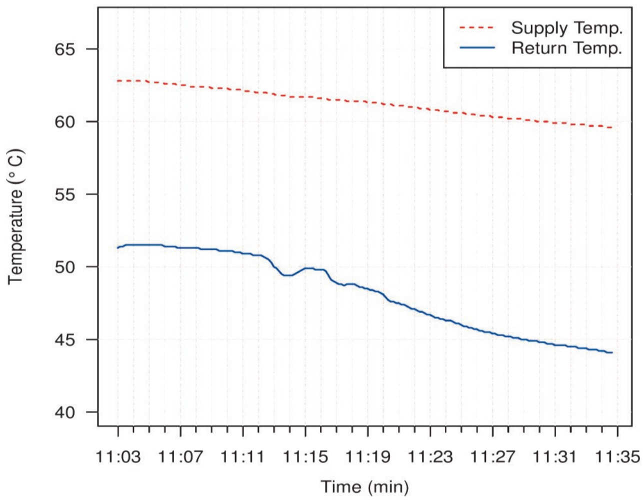


(b) Volumetric Flow ($\frac{m^3}{h}$) of the "Old workshop".

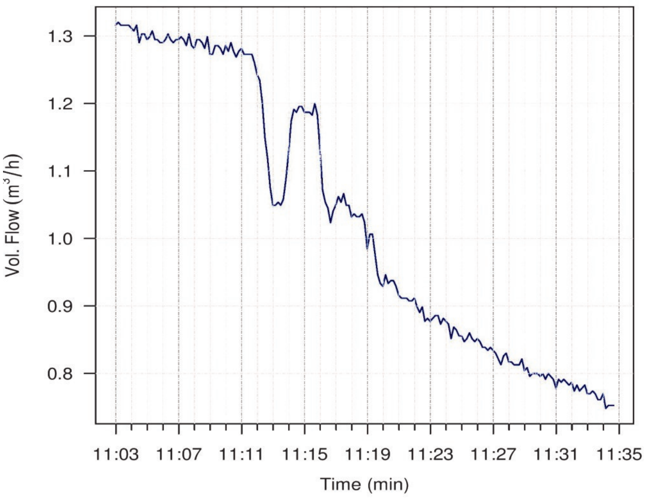


(c) Heat Flow (kW) of the "Old workshop".

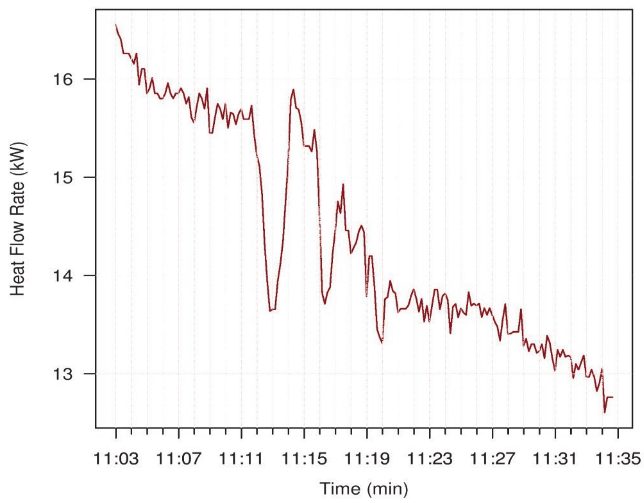
Figure 13: The plots show the measurements made at the "Old workshop" (at Basement) in the time window from 07.12.2012 to 10.12.2012, where the major ticks mark the start of a day (00:00 hours), the minor ticks are separated by one hour and the middle ticks represent the noon (12:00 hours) of the corresponding day. From top to bottom, the first plot shows the Supply and Return temperature in °C, the second plot shows the volumetric flow in $\frac{m^3}{h}$ and the last the heat flow rate in kilowatt (kW).



(a) Supply (dashed line) and Return (solid line) temperatures (°C) of the of the "Transfer centre for special wastes".

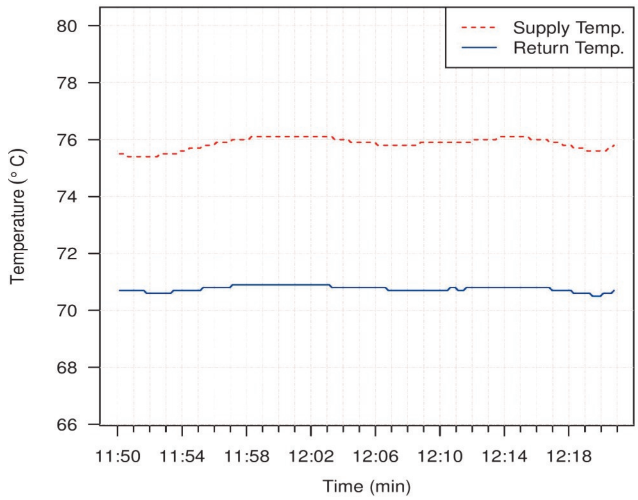


(b) Volumetric Flow ($\frac{m^3}{h}$) of the "Transfer centre for special wastes".

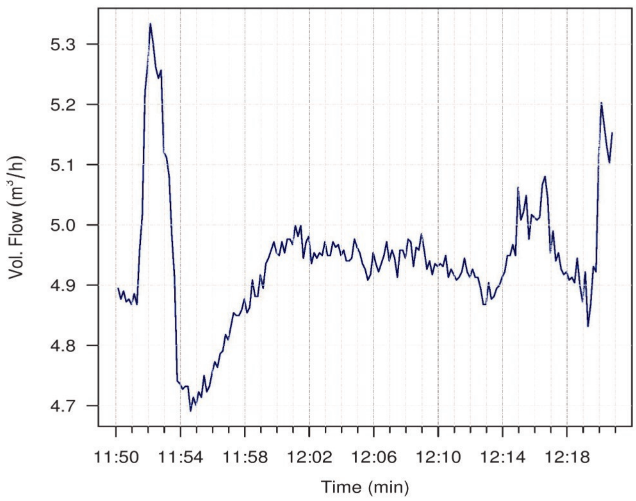


(c) Heat Flow (kW) of the *"Transfer centre for special wastes"*.

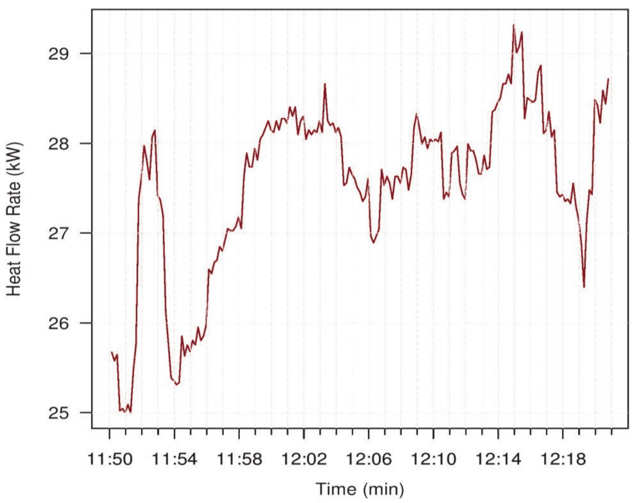
Figure 14: Measurements at the "Transfer centre for special wastes" in the time window from from 10.12.2012 11:03 to 10.12.2012 11:35. From top to bottom, the first plot shows the Supply and Return temperature in °C, the second plot shows the volumetric flow in $\frac{m^3}{h}$ and the last the heat flow rate in kilowatt (kW).



(a) Supply (dashed line) and Return (solid line) temperatures (°C) of the of the "New Workshop".



(b) Volumetric Flow ($\frac{m^3}{h}$) of the "New Workshop".



(c) Heat Flow (kW) of the *"New Workshop"*.

Figure 15: Measurements at the "New Workshop" in the time window from from 11.12.2012 11:49 to 11.12.2012 12:20. From top to bottom, the first plot shows the Supply and Return temperature in °C, the second plot shows the volumetric flow in $\frac{m^3}{h}$ and the last the heat flow rate in kilowatt (kW).

8 Conclusions

The use of ultrasonic mobile sensors is an advantage to analyse these kind of systems at different points and times, where it is only useful for short term analysis (1 week) and not for long term measurements. The measurements presented in this paper should help take the decision to install fixed temperature and flow meters to calculate the heat consumption of the most important areas. The results showed a general representation of the behaviour of the system during different periods of time. It was observed that sometimes at specific areas the system consumed more energy than other times, where the measurements showed that the return temperatures reached at certain hours of the day the supply temperatures and giving heat losses to it. Sometimes they also showed that the supply temperatures decreased to the same level of the return temperature, where it was discussed that this fluctuation was caused by the heat transfer of two bodies with different masses.

It is expected, from this case study research, that for future investments, these measurements can help provide the user some reference of the behaviour of the system during several hours of the day and particular areas, and that the installation of an historical database for the already installed fixed flow meters with temperature options will benefit to optimize the heat losses of the system and provide reporting solutions to maintain a cross -reference with the monthly/yearly bill of the CHP's supplier.

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