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Monitoring Guidelines for Energy Efficient Buildings and District Heating Plants

CONCERTO INITIATIVE
Class 1

Cost-effective Low-energy Advanced Sustainable So1utions

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Monitoring Guidelines for Energy Efficient Buildings and District Heating Plants

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1. PREFACE: THE CLASS 1 PROJECT

The idea of the project CLASS 1 is to use the strengthening of the energy requirements to boost and drive the technological developments and to prove the economical and environmental benefits of ultra-low energy buildings (50% below the new requirements in the Danish building regulations) integrated with biomass- and solar heating based renewable energy supply.

In this context the Scientific & Technical objectives are to:

1. Optimise the integration of low-energy building technologies with supply (renewable and conventional) and distribution (heating and electricity) technologies;
2. Advance selected technologies within the 3 areas: low-energy building, renewable energy supply and distribution;
3. Improve the design, checking and verification procedures (this relates directly to the implementation of the building energy performance directive -EPBD);
4. Integrate the European ecolabel in the building projects (houses and components);
5. Demonstrate large scale implementation at close to market technical and economical conditions.

The Class 1 project is focused on the optimisation of sustainable energy systems in local communities, through an innovative integration of RE technologies with ultra low-energy buildings.
The bio-mass CHP system produces electricity and heat that are distributed directly to the use for heating in an innovative local district heating system for the dense, low-rise houses, and through the electricity network to heat the single family houses by heat pumps. Solar heating systems integrated in the network – and individual systems on the single family houses will be supplementing the CHP and taking over the in summer months when it is shut down. An advanced Building Energy Management System will control the energy supply, the thermal storages (for solar and for heating energy pulses from the CHP plant).
The Class 1 project has been designed to demonstrate that sustainable energy solutions in which integrated energy efficiency and renewable energy sources are economically viable, and technically and aesthetically acceptable.

The project also has special focus on the Indoor Environmental Quality (IEQ) to make sure that the energy savings are met without reducing the IEQ standards set out in the design specification phase. The IEQ focus is one of the areas in which the Class 1 project involves partners from other EU countries who are experts in respectively lighting and thermal comfort issues. Also trans-national cooperation is introduced for the socio-economic research part of the project, which deals with the user point of view (priorities, etc.) in the participating countries.
The Class 1 project demonstrates improvements to 6 individual technologies (windows, slab and foundation insulation systems, bio-mass gasification, local district heating distribution networks, ventilation heat recovery combined with heat-pumps and BEMS) and an innovative integration of these technologies (with solar heating) which lead to improved cost effectiveness.

This document aims to provide a methodology for planning, managing and reporting buildings and district heating plants monitoring campaign.

2. INTRODUCTION

The monitoring campaign on a new, or on a refurbished, building is usually strictly connected with the *Energy Performance Certification* or *Demonstration* procedures. The aim of monitoring is then, in different cases:

- to verify that all systems work as expected and
- to check energy consumptions/possible savings (certification);
- verify the actual indoor climate in the building (demonstration);
- to enable a comparison with the predicted use of energy and the predicted indoor climate (demonstration).

3. MONITORING CAMPAIGN ROAD MAP

Planning and executing a monitoring campaign requires first of all the definition of the objectives. The Road map of a monitoring campaign consists then of the following steps.

3.1 Objectives definition

The main possible objectives of a monitoring campaign can be identified as follows, in order of increasing complexity and detail of monitoring plant.

- *Energy performance Certification*
- *Demonstration*

3.2 Problems identification

For each possible objective, a list of possible problems/items-to-study can be defined

- *Thermal indoor climate and IAQ*
- *Energy performance*
- *Plants efficiency*

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Once the objectives and problems are identified, the detailed monitoring procedures have to be defined. These procedures involve the following items:

- What and how to measure;
- Where to take measurements;
- Duration of campaign and when to take measurements;
- Logging interval.

In general, each building is characterised with its own particularities, then following lists and tables have to be considered as a comprehensive review of what should/can be taken into account in each case.

3.3 What to measure: Listing Parameters

Outdoor conditions

Outdoor conditions are important in order to check if the monitoring period is representative of climate conditions of the site: if not, the results of monitoring campaign (energy consumption for space heating) should be corrected to a reference year using the degree-day method.

Parameters to be monitored in order to have a comprehensive outdoor conditions overview should be:

- ✓ Outdoor Temperature
- ✓ Outdoor Relative Humidity
- ✓ Wind speed and direction
- ✓ Global Solar Radiation
- ✓ Atmospheric pressure

For most buildings monitoring of Temperature (hourly values) and Solar radiation (daily) can be sufficient. For certification purposes it is probably sufficient to refer to meteorological data recorded at closest meteorological station, if available in proximity of the building.

Indoor conditions

Indoor conditions have to be characterized in order to demonstrate the overall well working of building. In general the following measurements could be complemented with a standard indoor climate questionnaire to find out how the users perceive the indoor climate, heating and ventilation system and how the building is used (e. g. occupancy profiles). Measurement have to take into account Indoor Environment Quality: Thermal comfort, IAQ and Visual comfort in one.

Thermal comfort

- ✓ Indoor air Temperatures
- ✓ Vertical Temperature difference
- ✓ Surface Temperatures
- ✓ Radiant Temperature asymmetry from windows or other cold vertical surfaces
- ✓ Operative Temperature within the occupied zone
- ✓ Relative Humidity
- ✓ Air Velocity within the occupied zone

IAQ

- ✓ Particles
- ✓ TVOC
- ✓ Carbondioxide
- ✓ Formaldehyde

Visual Comfort

- ✓ Illuminance

Plants

Plants are usually monitored by means of meters. A well monitored plants is often a well working plant. Metering per se does not save energy. It is the actions taken as a result of installing and monitoring meters that can achieve quantifiable energy savings. Meters that are selected and installed correctly provide the information for the monitoring and targeting process that is an essential part of energy management.

Metering systems play an important role in monitoring energy performance of buildings.

Actions taken as a result of installing and monitoring meters often save 5-10% of the energy
being metered. Sometimes they can save more. Metering helps building occupiers to understand where all the energy is going, and enables them to identify and monitor patterns of energy use.

Although the capital cost of individual meters has reduced in recent years, the cost of installing direct metering throughout a large building can still be significant. However, it is not always necessary to install large amounts of direct metering to establish end-use energy consumption: periodical readings on general meters can sometimes substitute a detailed metering plant. Very often meter can be substituted by a status (on/off) recorder: it is the case of constant flow pumps or constant velocity fans. In these cases recording operating time is sufficient and much less expensive than direct metering.

Energy and Water Consumption:

- ✓ Thermal (space heating and hot water)
  - Temperature drop
  - Flows
  - Fuel

- ✓ Electricity
  - Electricity use for heating / cooling
  - Electricity use for ventilation
  - Electricity use for pumps etc
  - Electricity use for lighting
  - Operating time
    - Different fan speeds
    - Lights
    - Pumps
- ✓ Water
  - Flows

Renewable Contribution:

- Temperature drop
- Flows
- Electric Power

3.4 The actual monitoring

For each particular project the above list serves as a guideline for the actual monitoring to carry out.
The application of the parameter lists to the different monitoring objectives is summarized in following tables by choosing which parameters to monitor.
The tables haves been filled out as a guidance, but should be adjusted for each project and its needs.
The legend/symbols used are:

X indicates that the parameters are recommended monitored

(X) indicates that parameters should be optionally monitored

X(a) indicates that parameters could be alternatively monitored

Monitoring item		External conditions: ✓ Climate definition											
Parameters		Ambient Temp	Relative humidity	Wind velocity	Wind direction	Global solar radiation	Atmospheric pressure						
Purpose of monitoring	Energy Performance Certification				(X)								
	Demonstration	X	X	X	X	X	(X)						

Monitoring item		Interior conditions: ✓ Indoor environment quality											
Parameters		Thermal							IAQ				Visual
		Room Temp.	Vertical Temp. Difference	Surface Temp.	Radiant Temp. Asymmetry	Operative Temperature	Relative humidity	Local Air Velocity	Particle	TVOC	CO2	Formaldehyde	Illuminance
Purpose of monitoring	Energy Performance Certification	X											(X)
	Demonstration	X	(X)	(X)	(X)	X	X	X	(X)	(X)	X	(X)	X

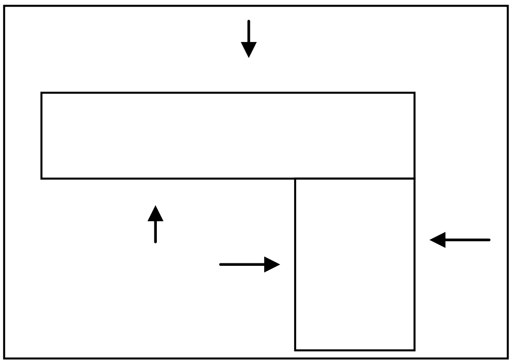
Monitoring item		Plant: ✓ Energy efficiency / Water consumption ✓ Renewable contribution											
Parameters		Thermal			Electricity					W	Renewable		
		Temp. drop	Flows	Fuel	Elect. Meter for heating/cooling	Elect. Meter for ventilation	Elect. Meter for pumps	Elect. Meter for lighting	Operating time for fans and pumps	Water flows	Temp. drop	Flows	Electricity
Purpose of monitoring	Energy Performance Certification	(X)	(X)	X	X			X	(X)		X	X	X
	Demonstration	X	X	X	X	X(a)		X	X(a)	X	X	X	X

3.5 How to take measurements

Two main typologies of monitoring campaigns can be distinguished: continuous campaigns and spot campaigns. The first type requires, specific monitoring plants, with capable dataloggers and an amount of sensors: can be quite expensive and it is usually justified only in case of demonstration buildings. The second one can be used with portable data loggers and periodical readings of meters (electricity, gas, water) at defined intervals (weekly, monthly) in case of certification and commissioning.

3.6 Where to take measurements

Each building has its own characteristics, then monitoring plan has to be specifically designed and tailored.
In general, thermal comfort measurements should be taken in at least one room for each **main building facade.**



For building with **more than three floors** it should be important to take measurements at **different levels**.

In case of public buildings, further data should be recorded in atria and corridors in order to give information on general indoor climate and on differences between rooms and passage environments.
Vertical temperatures difference can be recorded in rooms higher than 3,5m in order to make evident stratification phenomena.

Operative Temperature, and Radiant asymmetry as well, should be recorded at selected rooms, preferably where radiant asymmetry can be an issue (in windows proximity etc.).
Daylighted zones of the selected space should be defined prior to the selection of the measurement points. These zones should be defined based on their distance from the window, (or atrium skylight), and based on the activity in the zone. Measurement points should represent typical illuminance in each daylighted zone. The number of daylighted zones and test points depend on the dimension of the space, and on the activity.
A private office with sidelit window should not have more than 2 test points, one for each daylighted zone, one of which has to represent a dark area. A minimum of one test point at the working plane level (75 cm above the floor) should be monitored. The test points on the sidewalls should be about 1 meter away from the walls, and measured at the working plane level (75 cm above the floor).

3.7 Monitoring duration and logging intervals

For demonstration purposes, long term monitoring programme (heating and cooling seasons; one year) should be planned accordingly to the climate of the building site, especially for all parameters included in the BEMS. However, even in presence of a building energy management system, acquisition of parameters not included in integrated system would be advisable, according to what stated in the above mentioned tables.
As already mentioned, continuous long term monitoring can be very expensive, if not yet foreseen in BEMS, as alternative it is possible to develop (or integrate what already foreseen in BEMS) a system in order to monitor selected parameters for one or two weeks during significant periods. These periods are:

- ✓ 'Border periods' of heating and cooling seasons (Start and end of heating period Start and end of cooling period)
- ✓ Midwinter
- ✓ Midsummer

Logging interval is an important parameter in monitoring campaign: detailed studies require shorter logging intervals. In general, as more innovative the building is, as more detailed the monitoring campaign should be.
The following table summarizes *minimum requirements* for appropriate monitoring duration and logging intervals for different monitoring purposes

Purpose	**Location**	**Type**	**Duration**	**Readings intervals**	**Logging Intervals**
Certification	external	refer to closest meteo station	one year		
	internal	Spot	one year	Monthly	
	plants	Meters readings	one year	Monthly	
Demonstration	external	Continuous	one year		sub hourly
	internal	Continuous	one year		sub hourly
	plants	Continuous	one year		sub hourly

4. Data Analysis

The data gathered can reveal useful trends between, say, day/night, summer/winter, weekday/weekend. It can allow operators to:

- ✓ compare actual consumption with targets
- ✓ spot things going wrong before it is too late
- ✓ maintain one year moving averages
- ✓ Cumulative Sum plots to see which way trends are going.

4.1 Local Weather

In order to understand if monitored period climate values are on line with average local climate, all value will have to be compared to reference data. Typical analysis of weather data are:

- ✓ Temperature: Monthly min, mean, max (comparison to reference data)
- ✓ Degree days: comparison of measured data to reference data
- ✓ Solar Radiation: comparison of monthly measured data to reference data
- ✓ Wind diagram (frequency and maximum velocity per direction)

4.2 Energy consumption

Energy Demand: Electricity

	[kWh/m^{2}a]	Total annual (kWh)
Total electricity		E1
Electricity consumed by ventilation		E2
Electricity consumed by heating		E3
Electricity consumed by DHW		E5
Electricity of kitchen		E6
Electricity consumed for lighting		E7
Primary Energy (Total electricity)		PE_E

Energy Demand: Thermal

	[kWh/m^{2}a]	Total annual (kWh)
Total incoming heating energy (district heating/solar/gas/oil), measured from the main supply line (temperature drop/flow vs. oil/gas consumption*Heating value)		T1
Heating energy consumed by ventilation		T2
DHW		T3
Primary Energy (Total thermal)		PE_T

Contribution from Renewable

	Total annual	Renewable fraction
Solar Thermal	R1	R1/T3 (R1/T1)
PV	R2	(R2)/E1

Water consumption

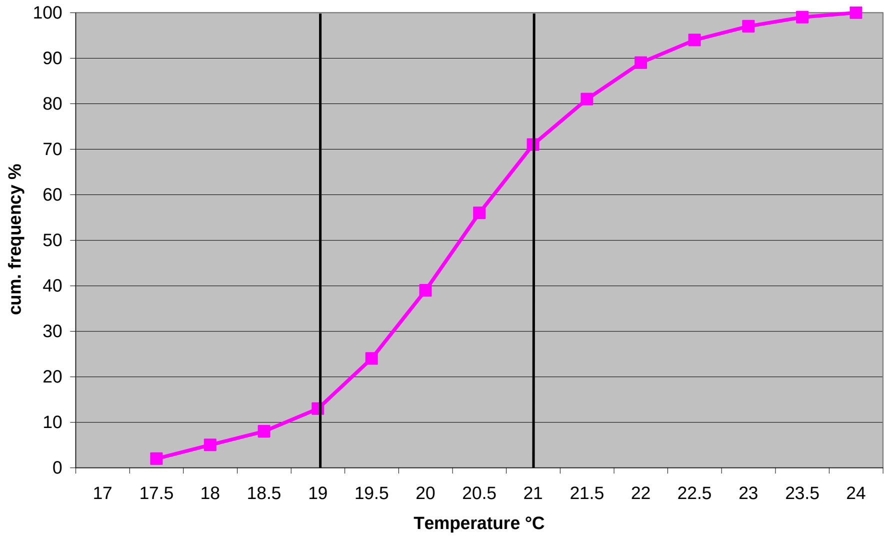
		Total for the whole building
Water	… m^3/m^{2}a	… m^3/a

Primary energy calculation

		Total for the whole building
Space heating	… kWh/m^2 a	… kWh/a
DHW	… kWh/m^2 a	… kWh/a
Electricity	… kWh/m^{2}a	… kWh/a

4.3 Thermal comfort

A convenient way of representation of thermal comfort is cumulative frequency curves of calculated PMV (PPD) *during working hours*. As alternative the cumulative frequency curves of Air Temperature (better: Mean Radiant Temperature) *during working hours* can be adopted.



Percentage of time with 0.5>PMV>-0.5	
Percentage of time with 19<Ta<21 (Winter)	
Percentage of time with 25<Ta<27 (Summer)	

5. DISTRICT HEATING NETWORK AND PLANTS MONITORING GUIDELINES

The Class1 project wants to demonstrate how a new district heating network based on “load sharing” from a number of different CO2-friendly technologies (biomass CHP, large solar heating plants, heat pumps) can be integrated in a housing area with varying heating energy demands.

To evaluate the viability of this innovative technological solution, the data related to the district heating network and the related plants have to be monitored accurately.

It is thus important to monitor the energy flows of the distribution network, the energy contributions of each plants, and the in/out temperatures.

In particular, the following data have to be metered.

Plants/district heating network:

- The flows, the delivery and returns temperatures for the large solar heating system;
- The flows, the delivery and returns temperatures and the electricity produced by the biomass gasification plant;

District heating network/dwellings:

- The flows, the delivery and returns temperatures for each dwellings (these data would be metered anyway for billing purposes).
- In-door temperature logging at selected consumers to detect unbalances and other insufficiencies in the heat supply.

The information about the energy flows can be used to produce load duration curves and hourly/daily energy consumption diagrams.

To compare the system performance in different years, information about the climate should be utilized to adjust for annual variation of the climate conditions. For example by means of the degree-day method.

Notices that changes in the heat consumption due to disconnections or connection of new customers should be taken into account.