Standardized energy measurement concept for data centers and their infrastructures

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Masthead

Contents

Accepted modifications

The following modifications are accepted by the parties and are covered in the corresponding individual chapters in the list of specifications.

N°.	Date	Index	Signature	Entitled
1	4.4.2008	2	MAUC	Merge of the A+W and Willers reports
2	25.4.2008	3	MAUC	Corr. according to Aebischer e-mail of 11.04.08
3	2.5.2008	4	MAUC	Aebischer data table integration
4	30.6.2008	5	MAUC	Insertion of abbreviation glossary

List of the main abbreviations

AHU: Air Handling Unit.

Critical MCC (Motor Controlled Center): motorized systems outside of computer racks which need to be supplied with backed-up power (for example pumps, ventilators, etc.).

C1 = DCiE = 1/PUE

DCiE = 1/PUE = C1

EJPD: Federal Justice and Police Department.

CSV file: A CSV file is a tabular file containing data on each line separated by a separator character (generally a comma or a semi-colon).

GEN: Diesel motor type back-up group.

Gen Sw Gear: electricity distribution cabinet for the back-up power supply

IEC: International Electrotechnical Commission.

M-bus: The M-Bus (Meter Bus) is a European standard for remote reading of heat or electricity meters.

Mech Sw Gear: electricity distribution cabinet for ventilation and air conditioning systems.

No-break: Uninterruptible electrical power supply systems with flywheel.

NOE: New Electricity Supply developed by the utility Geneva Industrial Services.

OPC: OLE (object linking and embedding) for Process Control is a technical specification defining a standard set of interfaces based on OLE COM/DCOM technology developed by Microsoft.

PDU: Power Distribution Unit.

SICC: Society of Heating and Air Conditioning Engineers.

UPS/ASC: Uninterruptible power supply system, battery-powered inverter.

Utility Sw Gear: Main electricity distribution cabinet.

1 Presentation of the study

The Standards Commission of the Canton of Geneva mandated Bernard Aebischer from CEPE (Centre for Energy Policy and Economics) at ETH Zürich to prepare a standardized measurement concept for DCiE.

DCiE is the ratio between the electrical energy consumed by the IT equipment inside a data center and the total electrical energy needed for the correct functioning of the same data center (IT equipment and infrastructure).

DCiE = 1/PUE = C1 =

$$\text{DCiE} = 1/\text{PUE} = \text{C1} = \frac{\textbf{Electricity consumption of IT equipment}}{\textbf{Total electricity consumption of the data center}}$$

This measurement concept shall then be used by mandated engineering firms to measure DCiE of individual data centres. The collected data of all data centres will be pooled together in a benchmarking process. To get comparable data, the measurement concept must present a clear methodology to perform measurements according to the same principles, in order to guarantee reliable results and optimal costs.

This document has been jointly drawn up by Amstein + Walthert Genève SA and Jobst Willers Engineering AG.

2 Methodology

2.1 Consumers to take into account

The different main consumers to take into account for the coefficient DCiE measurement are presented in the table below. We also give some comments regarding the measurement principle and the possible alternatives.

The comments are of a general nature and an in situ analysis/study of the data center and building configuration is indispensable before installing energy meters.

The main difficulty remains the calculation of the electrical energy consumed by air conditioning as, in most cases, a single cooling system supplies refrigeration to the whole building housing the data center.

Main consumers	Comments on energy measurements
IT equipment (computer racks and servers).	Measuring devices to be installed on the PDU(s) incoming power supply line if power is supplied only to the IT equipment. Otherwise, one meter per outgoing power supply line from the PDU(s).
Uninterruptible power supply systems (UPS/ASC, No-break)	The short-break back-up units (ex: diesel back-up units) may be disregarded as they have very little or no electricity consumption in "stand-by" and "operating" mode, unlike no-break systems.
Server room lighting	If the lighting is not powered by the PDU or a specific power supply unit for the server room, a specific electrical meter should be installed to measure the energy consumed by lighting. If the lighting power supply comes from a unit shared by the whole building, it is possible to calculate the installed capacity in person and install a light-detecting meter.
Air conditioning cabinets	Most data centers are cooled using air conditioners located in the data center itself or in adjoining premises. The electricity consumption of these devices can essentially be imputed to the ventilators, but sometimes also to directly integrated thermodynamic systems (compressors – Split system).

Main consumers	Comments on energy measurements
Ventilation	If an air handling unit (AHU) is dedicated exclusively to the data center, then it will be necessary to install an electricity meter on this AHU. Proposal: if the air renewal system of the data center is part of a general AHU for the building, for which the total flow is >80% of the air renewal flow for the data center, then the consumption of this general AHU does not need to be measured.
Refrigerating machines	If the refrigerating machines supply refrigeration to consumers other than those dedicated to data center air conditioning, it will be necessary to install a refrigeration energy meter on the primary chilled water circuit as well as a meter on the secondary distribution circuit(s) to the consumers dedicated to data center air conditioning.
Air coolers and cooling towers	Measuring devices to be installed on the power supply unit of this piece of equipment.
Cooling pump(s)	If this (these) pump(s) is (are) supplied by a different electrical power unit from the power supply unit of the air coolers or cooling towers, or by a different electrical power unit from the hydraulic refrigeration distribution power supply unit, it must be fitted with an electrical energy meter, on the condition that its electrical power or the total electrical power of the pumps is above 1.5 kW
Primary and secondary chilled water pumps	If these pumps are supplied by a different electrical power unit from the hydraulic refrigeration distribution power supply unit, they must be fitted with electrical energy meters on the condition that their electrical power or the total electrical power of the pumps is above 1.5 kW (proposal).

Table 1: main consumers and particular comments

2.2 Configurations

The configuration of data centers is not uniform and varies strongly from one site to another and according to year of completion. This variety is the main difficulty in defining a "global and universal" measurement concept.

We can classify the data centers based on the electrical distribution topology and the type of cooling system.

2.2.1 Main electrical configurations

The electrical configuration types (electrical distribution to servers and infra-structure) are the simplest to define: for this purpose, we can take the 4 configu-rations presented by the Uptime Institute for "Tier Level" classification[1] (see Figures 1 to 3).
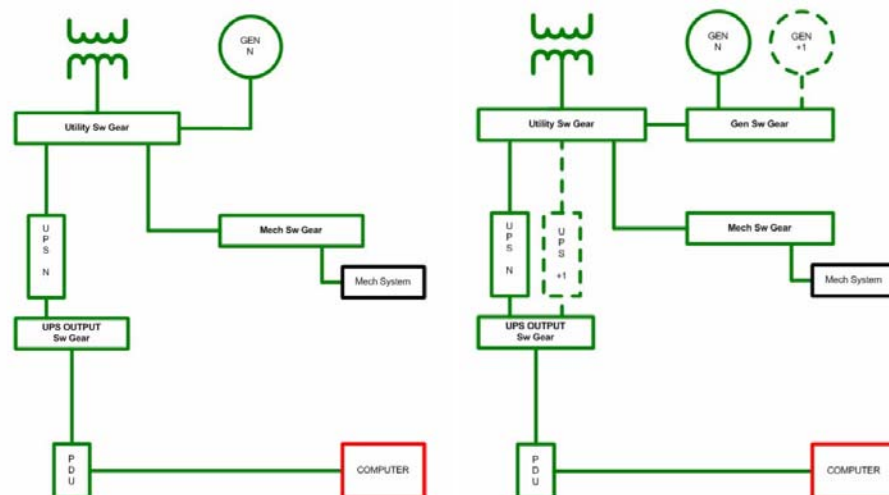

Figure 1: typical configuration of the electrical system topology of a data center at Tier Level I (left) and Tier Level II (right) – source: Uptime Institute
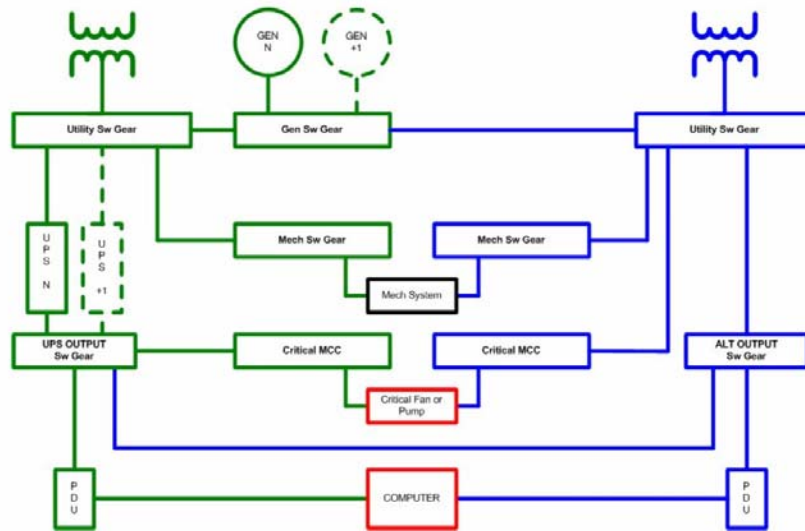
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[1] http://uptimeinstitute.org/content/view/22/56/

Figure 2 : typical configuration of the electrical system topology of a data center at Tier Level III – source: Uptime Institute
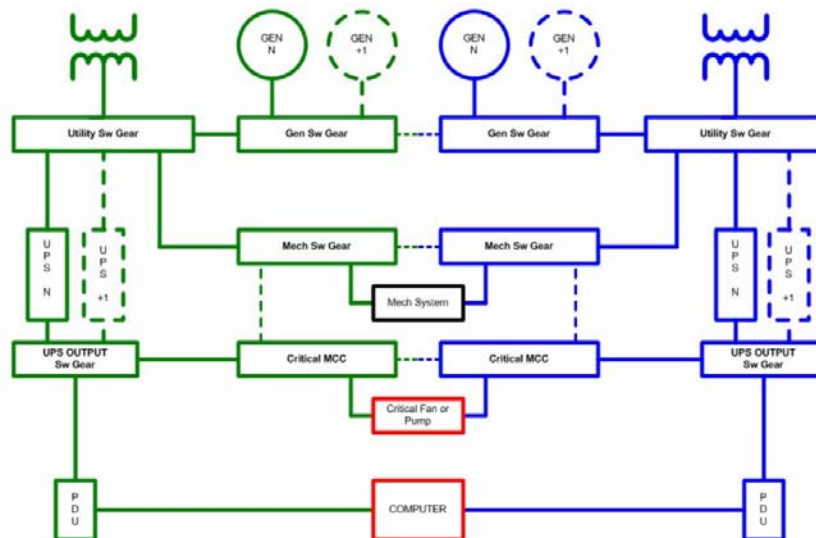

Figure 3 : typical configuration of the electrical system topology of a data center at Tier Level IV – source: Uptime Institute

Air conditioning systems for data centers can be classified in two main areas:

- Technology used: chilled water, direct expansion refrigeration system, cooling by air conditioning cabinet, centralized monoblock, autonomous racks, use of cooling towers, air coolers, air condensers, etc.

- Refrigeration production dedicated to the Data center or not.

It is in relation to this last comment that we shall distinguish the two main methods of measurement.

2.2.2   Refrigeration production dedicated to the Data center

This is the simplest and most favourable case for electricity measurement. To explain the measurement principle, we shall detail the distribution of energy meters on the schematic diagram of Tier Level IV (which is the most complex).

We present below two typical diagrams, which summarize certain comments from Table 1. When refrigeration production is dedicated to the data center, electricity measurements are simplified. However, it is advised to pay attention to the position of the electrical meter measuring the power supplied to the servers:

- The elctrical meter shall be installed on the PDU incoming power line if, and only if, the PDU only supplies power to the IT equipment (computer and server racks) and not to other ancillary component that is part of the infrastructure (lighting, decentralized ventilator, etc.).

- An electrical meter shall be installed on every outgoing power supply line of the PDU (so there may be several meters) from the racks and/or servers if the PDU supplies other ancillary components which are part of the 'infrastructure (lighting, decentralized ventilator, etc.).

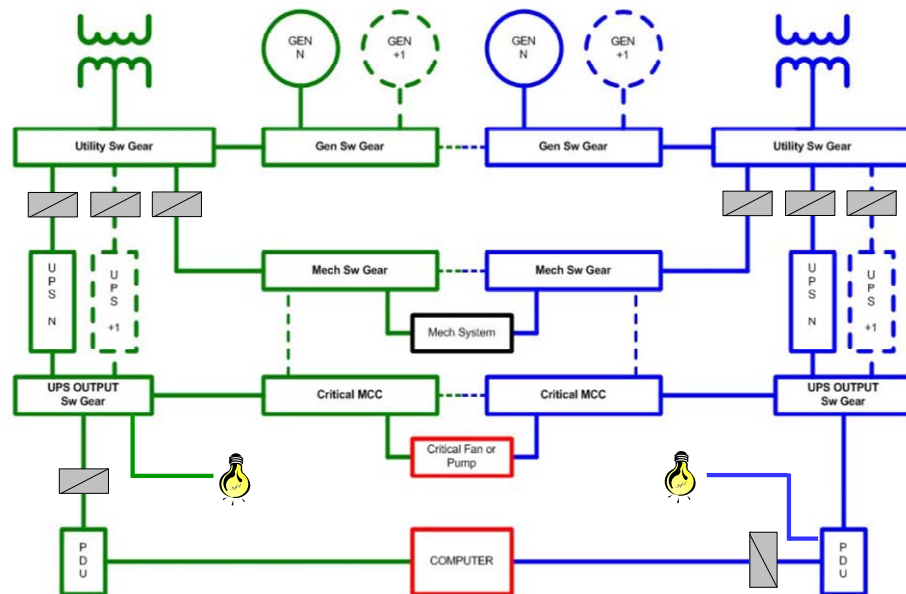These different variants are illustrated in figures 4 and 5.

Figure 4: measurement principle with dedicated refrigeration production and two lighting variants
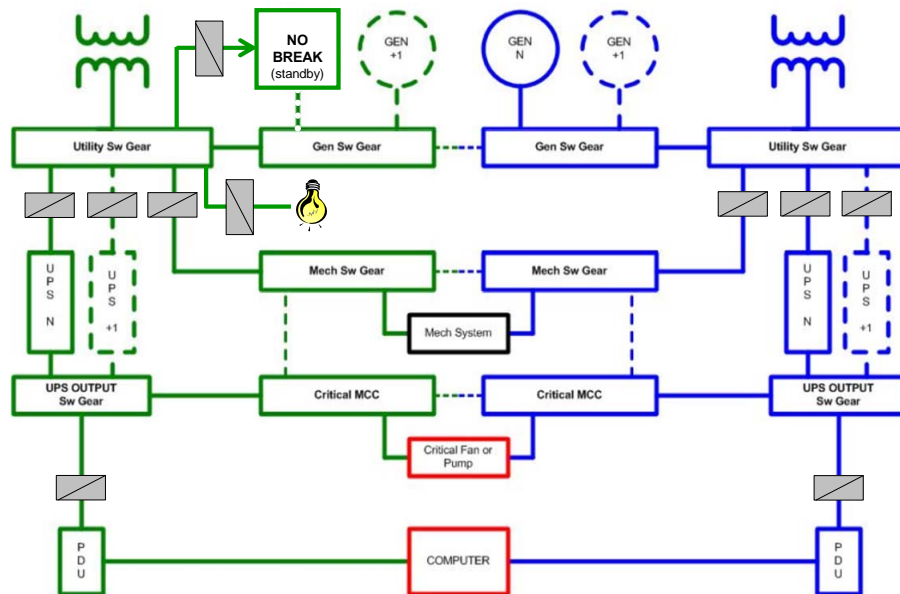
 Electricity meter

Figure 5: measurement principle with dedicated refrigeration production, another lighting variant and no break

2.2.3 Refrigeration production not dedicated to the data center

For refrigeration production not dedicated to the data center, we have produced a typical diagram which we feel reflects the vast majority of data center chilled water supply systems.

This is a system of chilled water production from 1 or 2 refrigerating units cooled by air via air coolers or cooling towers.

Based on this diagram (see annex 5.1), it is easy to deduce other system configurations such as cooling by water for example (one need only blank the air cooling system to have the measurement principle for water cooling of the refrigerating units (municipal water, river water, lake water).

To deduce the consumption of electrical energy dedicated to data center air conditioning, it is necessary to measure refrigerating energy. These measurements shall be taken:

- On the primary chilled water circuit to measure the total quantity of cooling energy produced by refrigeration machines.

- On the secondary circuit, on the outgoing line to consumers dedicated to data center air conditioning.
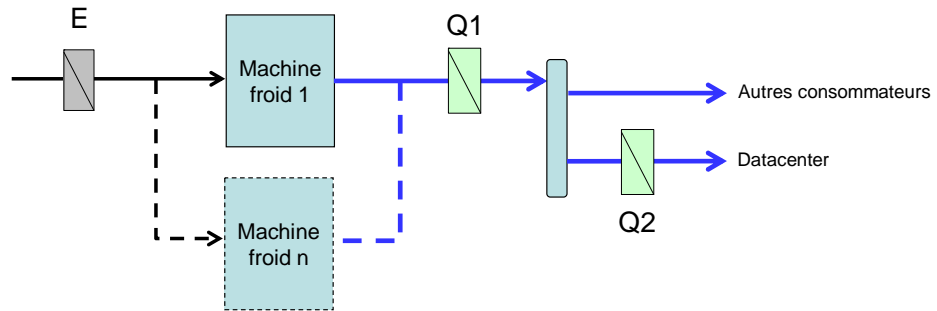
Figure 6: measurement principle for electrical consumption by refrigeration machines in the case of non-dedicated production

Electrical refrigeration energy for the data center shall then be calculated as follows:

$$Ed = E \times Q2 / Q1$$

With E = total electrical energy consumed by the refrigeration units

Q1 = total cooling energy produced by the refrigeration units

Q2 = cooling energy distributed to data center air conditioning

A reading of the measurements and transmission of data to the monitoring organization (for example CEPE Centre for Energy Policy and Economics) must be made at least every 2 weeks.

3 Energy measurement principle

3.1 Basic data

In building technology, there are different standards and directives for the logging and analysis of energy consumption. In Switzerland, the directive SICC 98-1 "energy and fluid measurement concept" establishes the basis for most projects.

On an international level, USA institutes and businesses are particularly involved in standardized consumption logging in data centers. Energy efficiency expressed by coefficient DCiE has been generally imposed.

3.2 Aim of the energy measurement concept

The energy measurement concept must create the conditions to reach the following goals:

- homogenous and consistent measurement concept,

- simple analysis with report on several installations,

- assessment of coefficient DCiE.

- presentation of areas to investigate for optimization measures.

3.3 Structure of the measurement concept

3.3.1 Data recording

Recording data can be done automatically or manually.

In the case of manual recording, the measurements are taken on-site, from meters, periodically. They are then entered into a table provided for this.

In the case of automatic data recording, it is advised to connect the meter to a bus system using the M-bus protocol. Using this system, it is also possible to read data in a monthly/weekly/daily or even hourly basis.

3.3.2 Measurement concept with M-Bus (OPC server)

The M-Bus is a system that has been developed to read data from the meter. The M-Bus has the following advantages:

- widely accepted by measuring device manufacturers,

- protected against polarity inversion,

- freedom of network topology: bus, star or tree-type,

- economical due to low installation costs.

Meter information is collected, via de bus, using a signal converter (master) It is possible to connect up to 64 M-Bus meters (slaves) to a signal converter. Once the meters fitted with an M-Bus interface are installed, they are directly connected to the bus. Meters that do not have an M-Bus interface are incorporated using an pulse meter on the M-Bus. The structure of the system with M-Bus appears as follows:
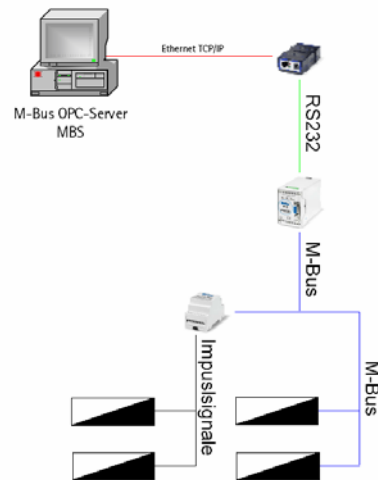
Figure 7: M-Bus system topology

The signal converters are connected to the OPC server using a TCP/ IP router.

In order to avoid excessive calculation loads, it is advised to avoid connecting more than 40 meters (maximum theoretical expansion: 254 components) to an OPC server.

3.3.3   Remote analysis

Remote data analysis can be beneficial in the case of a measurement concept aimed at several installations or a large data center. In this case, data transfer must be controlled using a web inquiry.
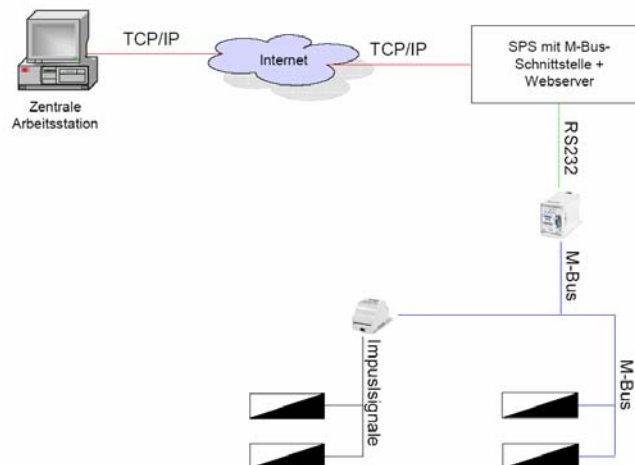

Figure 8: M-Bus system topology with remote analysis

For example, the structure of the system can be as above. Data can be re- corded using a Programmable Logic Controler (PLC) with M-Bus interface and integrated web server. The data can then be made available on the internet.

Another possibility consists of transmitting the data to the central workstation periodically by e-mail.

3.3.4 Data retrieval

There are many possible ways to retrieve data collected with the OPC server (M-Bus), the remote reading system via internet, or through manual readings.

For manual readings, the data recorded are entered into a table prepared in an MS Excel spreadsheet.

In the case of data recorded using an OPC server (M-Bus), the data is loaded via an OPC Datalogger. The latter provides a CSV file for processing at a later date. The data can be read either with an Excel spreadsheet, or processed using an analytical tool.

Regarding remote analysis via internet, the PLC provides a CSV file containing the data collected. The CSV file can be read either with an Excel spreadsheet, or processed using an analytical tool.

3.3.5 Measurement periodicity

We recommend that measurements are taken every ¼ of an hour. This time interval is sufficient for energy measurements and reduce the risk of overloading the memory of measurement devices.

3.4 Data processing

For the analysis of energy data, different tables and graphics must be provided for the user. The aim of these tables is to provide a clear overview of data center energy consumption.

Here below are the aims of these tables and graphics:

Controlling energy consumption

Here, the consumption data of an installation or system is monitored in order to determine the variations in energy consumption under constant load conditions.

Installations in the area of building technology (ventilation, heating, air conditioning) often work according to the outdoor temperature. Consequently, outdoor temperatures must also be taken into account in the analysis. (Meteosuisse supplies average outdoor temperatures by week and by month).

Infrastructure energy efficiency indicator (DCiE)

The energy efficiency of a data center (represented by DCiE) can be calculated on the condition that all the required values are recorded. This coefficient is obtained using the following formula:

$$DCiE = \frac{\text{Electricity consumption of IT equipment}}{\text{Total electricity consumption of the data center (infrastructures + IT)}}$$

The presentation of the data analysis can be divided as follows:

	Presentation	
	Graphic	**Table**
Energy flow diagram	X	
Overview per consumer, per week, month and year	X	X
Infrastructure energy efficiency coefficient (DCiE)	X	X
Energy consumption compared to the previous year	X	X
Overall overview by cost centre	X	X

Table 2: presentation of energy consumption data

For detailed analysis of the installations, it is advised to distribute the measurement points according to the different cost centres (installations, groups of installations, sectors etc.). The cost centre distribution differs according to each installation configuration and can be presented as follows:

- Refrigeration production, refrigeration distribution.
- Air conditioning and ventilation devices.
- Electrical devices, lighting, etc.
- Computer systems / racks.

4   Measuring devices

4.1   Requirements of measuring devices

An appropriate measuring device must meet the following requirements:

- according to decree SR 941.251 by the EJPD, regarding business premises, it is compulsory to install meters which are classed in accuracy category B at least. This corresponds to class 1 according to IEC 62053 -11 (accuracy of 1%).

- The device must have an M-Bus interface or impulse output to read measurement values and transfer energy data,

- Devices installed for electrical energy rebilling must be monitored and calibrated by certified calibration organizations. Specific provisions apply here regarding the periodical calibration of these devices. These provisions are described here below:

  If electrical energy is rebilled, meters must be calibrated by a certified calibration organization. The devices must be re-calibrated at regular intervals. Decree SR 941.251 by the EJPD specifies that active energy meters must be re-calibrated every ten years by a certified calibration organization. For electromechanical measurement system meters, the calibration frequency is 15 years.

4.2   Recommended measuring devices

4.2.1   Electricity measurements

We recommend the electricity meter ELKO. This device especially distinguishes itself by its good value for money compared with other competitors.

Device reference	Manufacturer	Data recording			
		DT*	Pulse	Analog.	M-Bus
DIZ D665DMi (indirect measurement)	ELKO	X	X		X
DIZ D651DMi (direct measurement)	ELKO	X	X		X

* DT = Time of Day Tarif
It is possible to read energy data on-site via a digital screen.

Table 3: recommended electricity meters

Energy meters have an M-Bus interface and a pulse transmitter. It is therefore possible to connect the device to a Programmable Logic Controler (PLC) via the M-Bus, or via the pulse transmitter. The measurement is taken directly below 65 A. Above this value, the measurement is taken indirectly using a current

transformer The mode of operation of the current transformer can be set on the device.

4.2.2   Thermal measurements

The recommended brands for thermal energy metering are Aquametro type Amflo Sonic (ultrasonic) Ambus.

4.3   Costs

4.3.1   Electricity meter

The average cost of an electricity measurement point without a datalogger is estimated at:

Meter (≤ 63A inc. M-Bus) + wiring + assembly = CHF 1'500 (EUR 1'000)

4.3.2   Heat meter

To avoid any additional pressure drop which would disrupt operation, we recommend installing ultrasonic heat meters.

The average cost of a heat measurement point without a datalogger is estimated at:

Meter + M-Bus interface + wiring + assembly = CHF 3'400 (EUR 2'300)

This estimate is based on a meter for a hydraulic line of DN50.

4.3.3   Datalogger

The datalogger is only necessary if the site does not possess a supervision system or if it is not possible to integrate measurement points easily, or if the client does not wish to integrate these points into their B.M.S. (Building Management System).
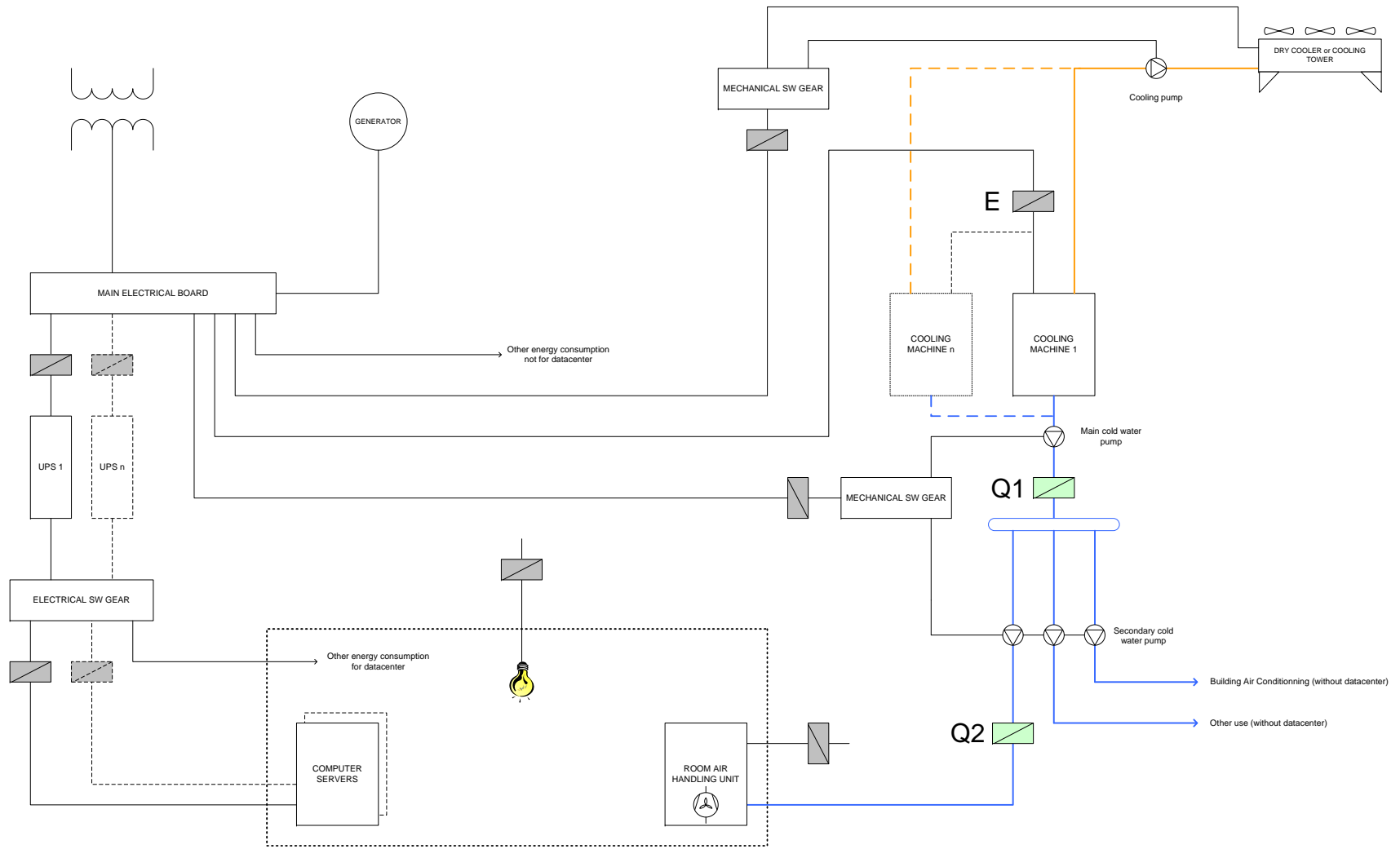
The average cost of a datalogger is estimated at:

Datalogger + program + commissioning = CHF 4'000 (EUR 2'700)

5 Annexes

5.1 Non-dedicated refrigeration production metering principle

5.2 Example of measurement results presentation

DRY COOLER or COOLING TOWER

MECHANICAL SW GEAR

Cooling pump

E

GENERATOR

COOLING MACHINE n

COOLING MACHINE 1

Main cold water pump

MAIN ELECTRICAL BOARD

Other energy consumption not for datacenter

Q1

MECHANICAL SW GEAR

UPS 1

UPS n

Secondary cold water pump

Building Air Conditionning (without datacenter)

ELECTRICAL SW GEAR

Other use (without datacenter)

Other energy consumption for datacenter

Q2

COMPUTER SERVERS

ROOM AIR HANDLING UNIT

ELECTRICAL ENERGY METER

ELECTRICAL WIRE

COOL ENERGY METER

COLD WATER PIPES

COOLING WATER PIPES

C1 MEASUREMENT INTO DATACENTER
Non-dedicated refrigeration production metering principle
Amstein + Walthert – 04.04.2008

AMSTEIN+WALTHERT

Annex 5.2 Example of data sheet

Data Centre nr   1
Location   Zurich

Current year   2006

Month	Total consumption	Consommation IT-equipment	DCiE	Mean electric load IT-equipment	Floor area IT rooms	Mean electric load IT-equipment by floor area	Mean outside temperature
	[kWh]	[kWh]		[KW]	[m2]	[W / m2]	[°C]
January	657221	490978	0.75	682	1500	455	-2.2
February	622156	454333	0.73	631	1500	421	0.0
March	744073	510267	0.69	709	1500	472	3.1
April	832835	506544	0.61	704	1500	469	8.8
Mai	925911	554581	0.60	770	1500	514	13.3
June	969427	551493	0.57	766	1500	511	17.7
July	1083802	626113	0.58	870	1500	580	22.5
August	1088671	623864	0.57	866	1500	578	14.7
September	1132036	648006	0.57	900	1500	600	16.9
October	1156820	679537	0.59	944	1500	629	12.7
November	1099209	667764	0.61	927	1500	618	7.0
December	999948	712962	0.71	990	1500	660	2.5
Total	**11'312'109**	**7'026'442**	**0.62**	**813**	**1'500**	**542**	

Past year   2005

Month	Total consumption	Consommation IT-equipment	DCiE	Mean electric load IT-equipment	Floor area IT rooms	Mean electric load IT-equipment by floor area	Mean outside temperature
	[kWh]	[kWh]		[KW]	[m2]	[W / m2]	[°C]
January	588127	389743	0.66	541	1500	361	0.5
February	540416	358771	0.66	498	1500	332	-1.1
March	631550	434849	0.69	604	1500	403	5.6
April	647777	392029	0.61	544	1500	363	9.3
Mai	726211	487646	0.67	677	1500	452	13.7
June	819132	433186	0.53	602	1500	401	18.3
July	769453	466029	0.61	647	1500	432	18.3
August	861543	536702	0.62	745	1500	497	16.3
September	692336	458961	0.66	637	1500	425	15.6
October	790281	446074	0.56	620	1500	413	11.0
November	738710	497624	0.67	691	1500	461	3.9
December	657221	429861	0.65	597	1500	398	-0.4
Total	**8'462'758**	**5'331'476**	**0.63**	**617**	**1'500**	**411**	