Designing a metering system for small and medium sized buildings

December 2010

Schneider Electric

Contents

1 Introduction

This article intends to describe a method to design the energy measurement system of a commercial building.

The scope of this article covers all WAGES consumptions in “non critical” buildings. Critical buildings such as hospitals, data centers have specific requirements regarding power quality that are not covered here.

2 Reference document

[1 Office reference architectures 3.1.1 - Antoine Jammes

[2] Guidance for electrical metering in federal building 2006 US Department Of Energy

[3] Metering Best practices 2007 - US Department Of Energy

[4] Measured Success: Constructing Performance Metrics for Energy Management - John Van Gorp

[5] Procedure for Measuring and Reporting Commercial Building Energy Performance - National Renewable Energy Laboratory

[6] Livre Blanc – Pilotage de la performance énergétique - GIE Bouigues

[7] GIL 65 Metering energy use in new non domestic buildings – CIBSE

[8] La mesure dans un projet d’efficacité énergétique 2008 – Gimelec

[9] Energy efficiency in Buildings Guide F – CIBSE

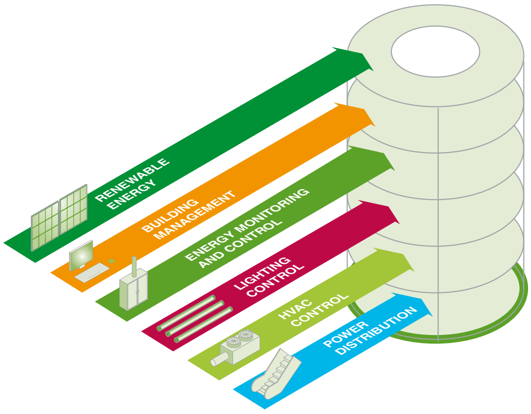
[10] Guideline for the evaluation of building performance – Building EQ Christian Neumann, Chris Jacob

[11] Solutions recommandées d’optimisation d’EE - E. Bernier

3 Energy Efficiency: up to 30% energy savings

The case for energy efficiency is clear. By 2030 electricity consumption will be over 70% higher than it is today in 2010[1]. By the same time, energy efficiency solutions will account for 57% of reductions in GHG emissions[2]. The American Council for an Energy Efficient Economy identifies energy efficiency and renewable energy as the twin pillars of sustainable energy policy. But what is energy efficiency? It is the ratio between energy consumed and energy produced. In other words, the ability to perform the same function with less energy – the goal of energy management. In a 2006 report, the International Energy Agency stated that improved energy efficiency in buildings, industry, and transport could reduce the world's energy needs in 2050 by one-third. It could also help cut GHG emissions, the single largest source of which is the energy used for buildings, particularly space heating[3], while electricity accounts for up to 50% of CO^2 emissions attributable to residential and commercial buildings.

Energy efficiency in housing could save vast amounts. In the EU so much energy is lost through roofs and walls alone that Europe could meet its entire Kyoto commitment by improving insulation standards. Similarly APEC energy ministers state in point nine of the Fukui Declaration: "Energy-efficient buildings and appliances are key to a sustainable future since the building sector accounts for two-fifths of energy use in the region."[4]



Solutions for all building applications

Passive and Active Energy Management

There are two approaches to energy efficiency: passive and active. Passive homes use insulation, heat recovery, and solar heating to achieve energy self-sufficiency. The passive approach alone is not enough, however. Energy efficiency is by its very nature a long-term effort that requires the active management of demand. The aim? That buildings should produce more energy then they create. The EU Energy Performance of Buildings Directive (EPBD) requires all new buildings to be nearly zero energy by 2020. By the end of 2010, however, the Masdar Headquarters building in Abu Dhabi, widely described as world's first positive energy building, will be completed. Most buildings will not be postitive-energy by 2020, however. They will be outnumbered by existing properties built before the EPBD (which only applies to Europe, anyway). In this respect, simple, cost-effective energy management can bring great improvements in energy efficiency. But whether buildings are existing ones or state-of-the-art positive energy buildings, the foundation of energy efficiency is metering and monitoring: they tell owners and operators how their building is performing. Furthermore, they produce substantial, almost immediate improvements. The first benefit is that it involves tenants, managers, and owners in energy efficiency action. The mere fact of being able to identify and quantify their energy usage prompts them to change their practices and patterns, cutting waste and avoiding peak rates, so lowering a building's operating costs and energy consumption. In a single-operator, owner-occupied office building, for example, the introduction of energy efficiency monitoring and measurement systems brings immediate energy savings of 10%.

---

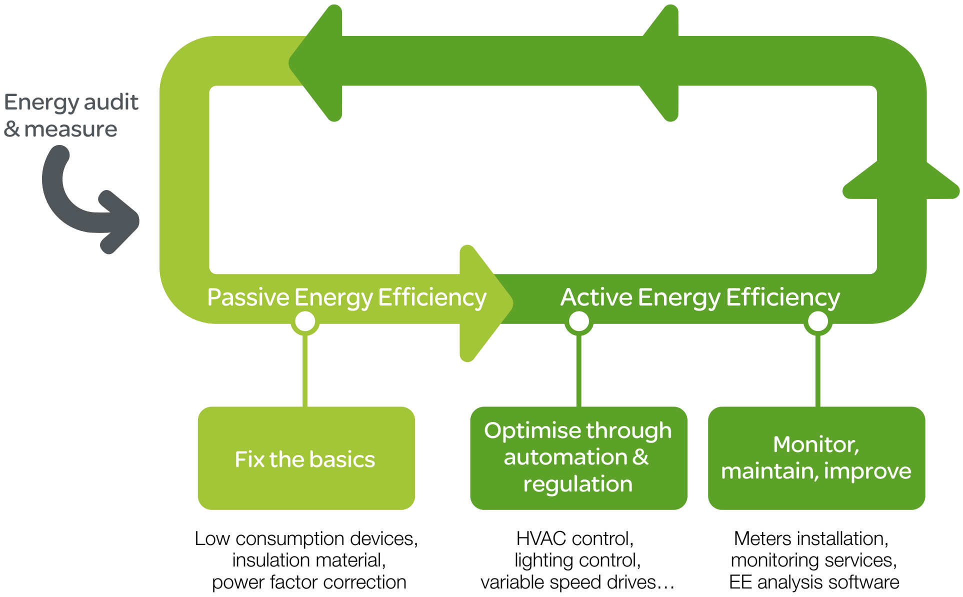
1 International Energy Agency, World Energy Outlook 2009
2 International Energy Agency, www.iea.org
3 www.eurima.org/climate-change/
4 Ninth meeting of APEC Energy Ministers (Fukui, Japan, 19 June 2010) Fukui déclaration on low carbon paths to energy security: cooperative energy solutions for a sustainable APEC.

Cornerstone of Energy Efficiency

Automated metering systems present information on dynamic display energy dashboards. Graphs, tables and widgets show information meaningfully, homing in on and tracking specific loads. A building's ventilation system may, for example, be overconsuming. A rapid solution is to reduce its motor's speed by only a few Hz with no ill effect on performance. More effective, longer-term contributions to energy efficiency are automation and control systems. They ensure that the only energy a building uses is the energy it needs. Such technology includes variable speed motors for ventilation, inside and outside lighting control, and smart thermostats and time programmable HVAC systems.

Another benefit of metering is that it provides detailed figures that help to optimise electricity supply contracts and renegotiate new ones. Multisite facility managers and building operators can also aggregate loads to negotiate bulk contracts. Accurate shadow bills help spot utility billing errors and whether suppliers are complying with contract terms. Continuous automatic metering is the cornerstone of effective energy management. It provides real-time information, alarms, and simple load control with some systems recommending corrective action. And, when measured against user-defined metrics, it can deliver historic and predictive energy intelligence for high-precision energy efficiency. It can help to:

- identify cost-cutting opportunities by spotting inefficiencies, trends and changes;
- manage demand to reduce exposure to price volatility or system reliability risks;
- improve energy usage by comparing energy costs across facilities;
- benchmark facilities internally and externally;
- allocate costs and sub-bill;
- improve load planning.

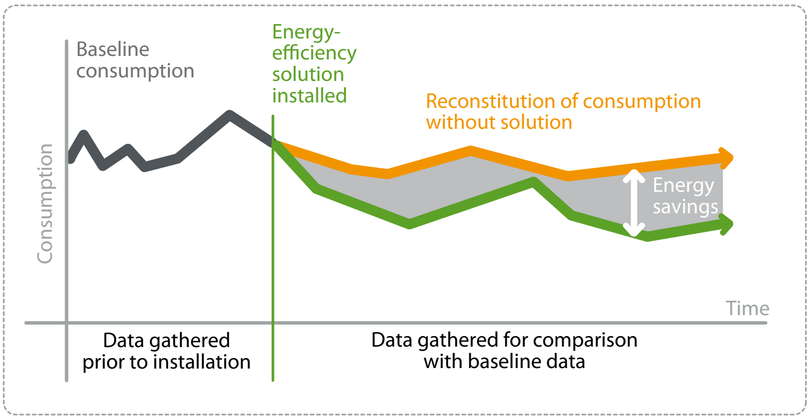


Metrics

To ensure that metering and auditing meet user needs and regulatory requirements, it is important to measure against meaningful performance metrics, e.g. kWh/m² and kWh/occupant for electricity consumption in an office. If a building is seeking certification to a standard like LEED for "green houses" or BREEAM, it measures and tracks its electricity use for each required space and function.

Similarly, users can know and show their ECM performance against an M&V metric like the IPMVP. In this way they avoid penalties and demonstrate where they stand with regard to their carbon commitments.

Achieve measurable savings

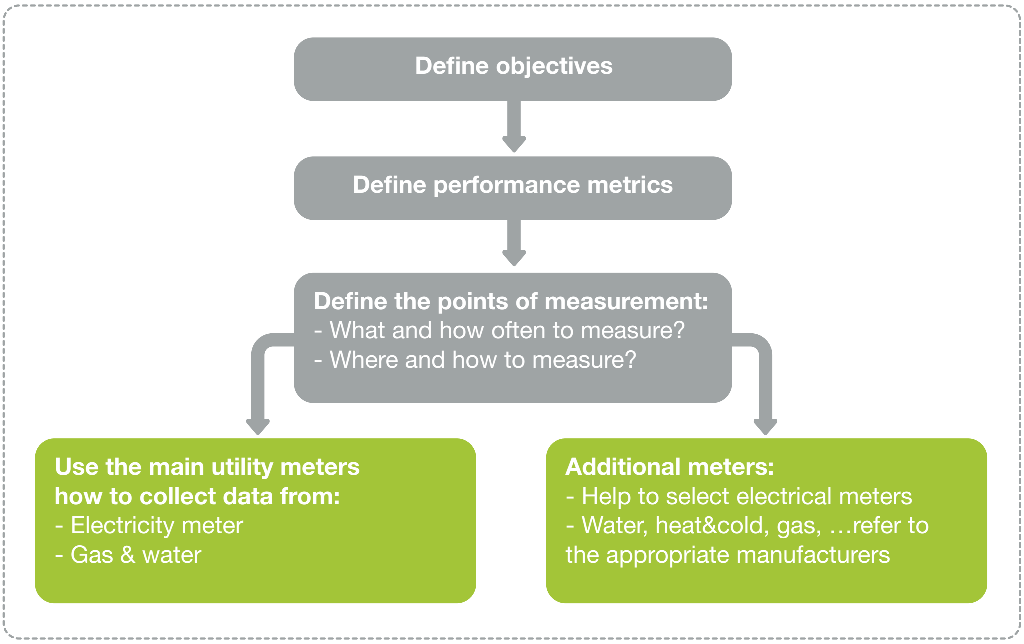


We use the International Performance Measurement and Verification Protocol (IPMVP) to measure and verify the energy savings we promise for our energy-efficiency solutions:

- Pre-installation audit: baseline energy consumption data are measured and calculated
- Post-installation audit: baseline data are compared with post-installation consumption data to determine actual savings

This white paper examines WAGES metering as part of the effort to achieve energy efficiency in non-critical buildings. It considers metering technology, metrics, and points of measurements. Energy efficiency is cost effective and earns rapid ROI. It increases property values, makes more attractive market prospects, and increases their rental occupancy rates and yield.

4 Proposed method



4.1 Define objectives

This first step shall be realized with the futures users of the system and enables to select the main principles of the solution to satisfy the objectives.

This step is essential to identity customer needs and to define the boundary of the energy monitoring system.

Main applications for an energy monitoring system are the following:
- energy cost allocation
- energy sub-billing
- energy usage analysis
- building energy performance benchmarking
- electrical distribution asset management
- energy consumption alarming
- bill auditing (shadow metering),
- regulatory or label compliance

These above objectives are generic and should be customized for each energy monitoring project

4.1.1 Energy cost allocation

Where cost allocation methods are allowed, energy costs are billed using a common formula, which is typically based on the square footage of the tenant relative to the total space of the building for rent. However, many tenants are beginning to consider these methods to be inaccurate and unfair and are asking to be billed only for their own usage.

Where a building has some form of metering in place, meters are typically manually read either by a service provider or by a designated individual or individuals employed by the property management company. The labour and data integrity costs of managing these manual systems can be high. Also, the typical lack of resolution in the data (i.e. one monthly kWh reading) provides no insight into the opportunities that may be available to better manage costs and allocation of coincident demand costs is not possible.

This is making accurate and reliable cost allocation a competitive requirement and, in some cases, a de facto standard.

Cost allocation

By measuring the consumed energy in different point of the network, provide the user with ownership of energy costs to the appropriate level in an organization. The main effect is to drive behaviour and then lower costs.

4.1.2 Energy sub-billing

For buildings that have no metering system in place, energy and demand costs are often not passed through to the tenants. For property owners that want to recover the costs of supplying electricity to individual tenants, a number of factors can interfere with implementing tenant sub-billing. For example, some countries prohibit billing based on sub-metering each tenant space.

Where local laws allow billing based on the use of sub-metering, this can improve billing accuracy; however, the cost of implementing a sub-metering system has traditionally been high.

Sub-billing

Based on accurate measurement at delivery point, in case of multi tenants presence, breaking apart the single bill into the exact consumption of each tenant gives ownership and motivation to conserve electricity. In addition sub-billing, for building owners, is a potential revenue source.

4.1.3 Energy usage analysis

The energy consumed by businesses is a significant part of their operating costs. In order to extract the most financial and competitive advantages from energy, users need to go beyond the traditional tactical approach of simply replacing inefficient equipment.

Energy usage analysis provides users with the means to maximise energy efficiency and minimise energy-related costs. It helps them understanding the characteristics of their energy consumption, identify opportunities with the largest payback, keep projects on track and verify results.

4.1.4 Building energy performance benchmarking

Benchmarking allows the users to compare the efficiency of one building or application (HVAC, lighting, IT) in an office buildings against others, or against Real Estate statistics. This will reveal inefficiencies and isolate key contributing factors, helping identify the right places to target improvement projects that won’t negatively affect people and business efficiency. This could include equipment upgrades, process changes, or optimising building performance according to weather conditions, occupancy or other drivers.

4.1.5 Electrical distribution asset management

Through permanent monitoring of his installation, the building facility managers and property managers need recommendations of a better usage and behaviour of their assets, to lower electricity consumption, capital expenditure and energy costs.

An Electrical Distribution asset management system will accurately meter energy consumption and demand throughout all each facility, automatically generate load profiles that provide insight into historical and present load patterns. This will reveal hidden, unused capacity by building, floor, feeder, zone or equipment. This spare capacity can then be better leveraged without the need for additional capital expenditures on upgrading. It will give the confidence that the existing infrastructure will handle changes linked to building occupancy modifications and will help minimize capital expenses by "right sizing" power distribution systems that meet but don't exceed the requirements of new facilities, expansions or retrofits.

4.1.6 Bill auditing (shadow metering)

Errors in the bills received from a WAGES supplier can be surprisingly common. Errors that benefit the building (i.e. under-billing) can be as problematic as those that are in the utility's favour (i.e. over-billing), as most supply contracts allow the utility to recover these missed charges months or years after the error occurred. For a commercial building this potentially means that costs are not recoverable from the tenants if new tenants are now occupying the space.

Potential sources of error can include inaccurate, misread or misentered energy data. A building could also be on the wrong tariff, or on a billing interval that is too long or too short, which can skew demand charges. Therefore, it is to the property manager's advantage to audit the billing received from the energy provider to identify any errors and/or anomalies and to have the information necessary to support claims for cost recovery.

A secondary meter typically called a "shadow meter" can be connected in parallel to the utility meter. A software will read energy data from this meter and will calculate an accurate "shadow bill" that can include all expected energy and demand charges. This bill can then be compared to the utility bill to identify any inconsistencies, either manually or by inputting the utility bill data into the software.

4.1.7 Energy procurement

Shadow billing and procurement are complementary applications. The level of benefits achievable through improved procurement strategies and better supply contracts are influenced by two factors:

- typically, larger energy consumers are in a better position to negotiate, particularly if the aggregate consumption among multiple buildings can be leveraged with a single utility,
- typically, enterprises in deregulated, competitive markets stand to benefit the most.

An Energy procurement system can deliver detailed energy and load profile histories as well as reliability and power quality summaries for all properties. It also offers tools to analyse and evaluate tariff structures (including real-time pricing) from single or multiple energy providers, comparing options using "what-if" scenarios. Using this breadth of information can help achieve the lowest cost without sacrificing reliability and quality of supply.

4.1.8 Demand/response

This function offers the consumer the ability to take benefits of discount electricity prices by reducing his consumption on demand of the Utility (could be on a case-by-case or a commitment basis).

A demand/response system will first help the user to evaluate whether participation in a specific event is economically advantageous. If it is, the system will help him quickly determine where and how much load he may be able to reduce in response to the curtailment request. Finally, it can help him efficiently coordinate a load curtailment strategy by automatically shedding loads or starting up generators during the event period.

4.1.9 Regulatory or labels compliance

There are several local regulatory that require energy metering for a building which exceed a certain area such as the Building Regulations Part L2 in UK:

> *"Reasonable provision of meters would be to install incoming meters in every building greater than 500m^2 gross floor area (including separate buildings on multi-building sites). This would include individual meters to directly measure the total electricity, gas, oil and LPG consumed within the building."*

And

> *"Reasonable provision of sub-metering would be to provide additional meters such that the following consumptions can be directly measured or reliably estimated...*
> *... b) energy consumed by plant items with input powers greater or equal to that shown in Table 13...*
> *... d) any process load... that is to be discounted from the building's energy consumption when comparing measured consumption against published benchmarks."*

Size of plant for which separate metering would be reasonable

Plant item	Rated input power (kW)
Boiler installations comprising one or more boilers or CHP plant feeding a common distribution circuit	50
Chiller installations comprising one or more chiller units feeding a common distribution circuit	20
Electric humidifiers	10
Motor control centres providing power to fans and pumps	10
Final electrical distribution boards	50

Table 13

Building owners may also decide to achieve a label (such as LEED, BREEAM, HQE…). Each of them have a special section about WAGES monitoring and encourage strongly the use of sub-metering either by area or energy use.

4.2 Define the performance metrics

Before starting to define any data to collect, it is much more important to define the necessary data to support and to meet the project goals. They are called the performance metrics and are the translation of the project goals into measurable data ([4]). They usually are part of the final energy dashboards.

The performance metrics enables to set a link between the building activity and the consumption

We give here below some examples of performance metrics.

4.2.1 Performance metrics for the EPBD compliance

If one of the project goals is to be compliant with the EPBD, two performance metrics which make up the EPC are mandatory for the whole building:

- Energy Efficiency Rating (KWh ep/m^2.year)
- Environmental impact (CO_2) Rating(kg eqCO_2/m^2.year)

4.2.2 Performance metrics for whole building benchmarking

For building benchmarking, we shall consider:

- Main supplies
- Renewable energies production
- Specific energy uses that are normally not typical of that activity sector (called separable energy use) or very different for each building such as laboratories in a university campus, leisure facility in an office building…

Including these energy uses may reduce the validity of the benchmark, they shall be deducted from the total energy consumption to compare values of different buildings.

To enable building benchmarking, it is also very important to normalize the consumption.

The data used may differ according to the activity sector, for example the performance metric for the total consumption is expressed in:

- kWh/m^2 and kWh/occupant for an office
- kWh/occupancy rate or kWh/overnight stay for an hotel
- kWh/ production rate for an industrial building

Data shall also be corrected with Heating Degree Days and Cooling Degree Days to compare the current building consumptions with the previous years and with buildings in others locations.

4.2.3 Performance metrics for Energy usage analysis

Performance metrics can be of type global performance such as global utilities consumptions (Gas, Electricity, Fuel, …) but could also be expanded to analyze deeper the building energy and water consumptions.

If an energy manager wants to understand and to have a clear picture of how energy is used in the building, to track deviations from a target, it is strongly advisable to be able to analyse consumptions per area and energy use.

The first step is then to make a breakdown of the building per physical area of homogeneous activity and major consumption:
- Outdoor
- Parking
- Catering
- Common area
- Tenant area
- …

The second step is to make a breakdown per energy use. Typical energy use breakdown in commercial buildings can be the following:
- Lighting
- Heating
- Cooling
- Ventilation
- Domestic Hot Water
- Other (office equipment…)

It is then possible to set up the metering strategy and define the performance metrics by selecting which energy use in which area has to be monitored.

	Outdoor	Parking	Catering	...
Lighting	●	●	●	
Ventilation		●		
DHW			●	
Cooling				
Heating			●	
Small power				

To be able to put a cross in the right cell, it is advisable to get an idea of the major consumptions in the building thanks to:
- Energy audit
- Building benchmarking
- Calculation with simulation tool

4.2.4 Performance metrics for bill auditing

For such application, knowing the global consumption is not sufficient to perform bill auditing and to reduce your energy bill especially for electricity. The most important is to be able to reproduce the tariff structure which depends strongly on the end-user contract.
For electricity, the following performance metrics shall be:
- Monthly consumption kWh per Time Of Use and corresponding costs
- Monthly peak demand kW and duration to calculate penalties for rated power overload
- Power factor and reactive energy consumption to calculate corresponding penalties.

This values shall be collected according to the same frequency than the main energy meter from the utility. Most of the time, a pulse from the main meter indicates this frequency (each 10mn or 15mn).

4.2.5 Performance metrics for LEED

There are several metering requirement to achieve a LEED label but it depends on the type of project and so do the related performance metrics.

> New Construction
Credit NC2009 EAc5 – Measurement and Verification - 3 points
Measurement and verification (M&V) involves recording actual energy use over the course of occupancy, and comparing that data with the estimated energy use seen in the design.
Performance metrics shall be defined according to the data calculated either by estimation or simulation.

> Existing Building in Operation
Credit EBOM2009 WEc1 – Water performance measurement
1 to 2 points
This credit requires the following performance metrics:
- Whole building water consumption with weekly data collection
--> 1 point
- Sub-metering at the system level with weekly data collection. The qualifying types of sub-metering for this credit are: irrigation, indoor plumbing fixtures/ fittings, cooling tower water, domestic hot water, or process water use.
--> 2 points

Credit EBOM2009 EAc3 – Performance measurement
System Level metering - 1 or 2 points
This credit encourages the use of building systems **submetering** to enhance the ability of operational staff to analyze specific energy loads and to pinpoint potential areas for improvement in system-level or equipment performance.
It requires:
- A breakdown of the largest energy use categories shall be done and cover 40 or 80 % of the total consumption (according ASHRAE energy audit)
- A minimum number of the previous categories to be covered at least by 80 %.

System Level Metering Requirements

Percentage of Total Annual Energy Consumption to be Metered	Number of Largest Energy Use Categories to be Covered by 80 % or more	Points
40 %	1 of 2	1
80 %	2 of 3	2

Metering must be continuous and data logged to allow for an analysis of time trends. The project team must compile monthly and annual summaries of results for each system covered.

> Credit EBOM2009 EAc4 – On site and Off-site renewable energy
1 to 6 points
Apart from using renewable energy systems, this credit requires also to submeter the energy produced by the renewable energy system in order to show the corresponding percentage of building energy use met by renewable systems.

> Commercial Interiors
Credit CI2009 EAc3 – Measurement and Verification - 2 to 5 points

- Case 1: project less than 75% of the total building area

--> 2 points
The credit requires installation of submetering equipment to measure and record energy use within the tenant space

- Case 2: project 75% or more of the total building area

--> 5 points
Continuous metering equipment shall be installed for several end uses with a Measurement and Verification plan

The performance metrics are then linked to the required end-use categories such as:

- Lighting systems
- Constant or variable motor loads
- Variable frequency drive
- Chiller efficiency
- Cooling load
- Air and water economizer and heat recovery cycles
- Air distribution and ventilation air volumes
- Boiler efficiencies
- Building related process energy systems
- Indoor water riser and outdoor irrigation systems

4.2.6 Performance metrics for BREEAM (UK)

The below metering requirements are mandatory to achieve a BREEAM label:
Issue Ene 2 – Sub-metering of substantial energy uses - 1 credit
Separate accessible energy sub-meters shall be provided for the following systems:
a. Space Heating
b. Domestic Hot Water
c. Humidification
d. Cooling
e. Fans (major)
f. Lighting
g. Small Power (lighting and small power can be on the same sub-meter where supplies are taken at each floor/department)
h. Other major energy-consuming items where appropriate.

Issue Ene 3 – Sub-metering of high energy load and Tenancy areas - 1 credit
Provision of accessible sub-meters covering the energy supply to all tenanted, or in the case of single occupancy buildings, relevant function areas or departments within the building/unit.

Issue Wat 2 – Water meter - 1 credit
Water consumption shall be monitor as follow:
1. The specification of a water meter on the mains water supply to each building;
2. The water meter has a pulsed output to enable connection to a Building Management System
(BMS) for the monitoring of water consumption.
There is special innovation credit achievable for sub-metering of individual areas where demand in such areas will be equal to or greater than of 10% of the total water demand of the building.

4.3 Define the point of measurement

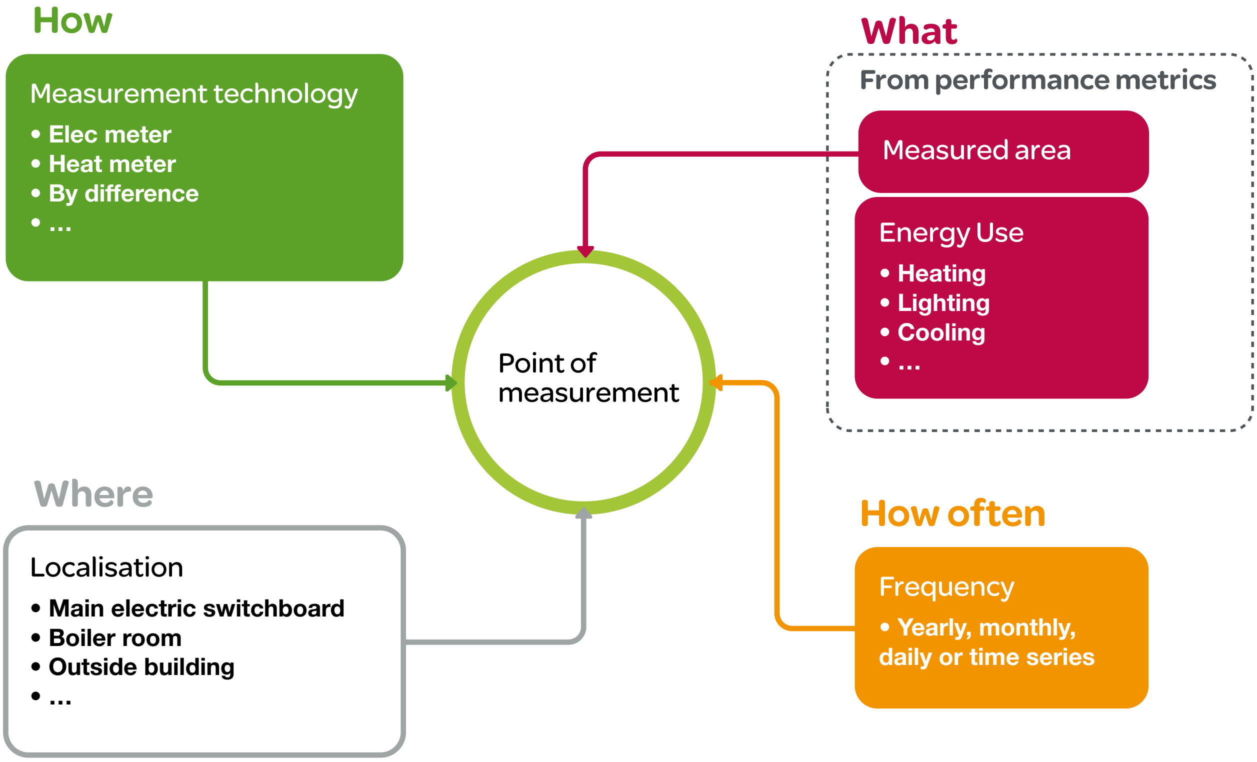
The purpose of the measurement system design is to ensure that the data collected will correspond to the desired analysis and results. This will allow the operation managers to monitor & control the building according to their objectives.

This will help to avoid:

- Insufficient data to enable building consumptions analysis
- Too much measured and collected data that are never used. However the investment cost to collect these data and the data storage cost is not negligible and could have been used for other energy efficiency actions.

The point of measurement is the combination of the meter and its location. To define the points of measurement in the building, we need to answer to the following questions:

- What are the data to compute the performance metrics? Which frequency?
- How to get the data and where to get these data?



4.3.1 What are the data to collect?

For each performance metric, the needed data can be split into 2 categories:

- Static data such as Building area, rating or efficiency of equipment. These data are usually used to normalize measurements for benchmark comparisons.
- Dynamic data such as energy consumption, temperatures, flows… with the corresponding recording frequency. The recording frequency depends on the project goals and could be yearly, monthly, daily or time series.

The table here below gives examples of these 2 categories for a commercial building:

	Necessary data to build the performance metrics		
Performance metrics	Static data	Building	Recording frequency
Building energy use intensity (kWh/m²)	Gross floor area (m²)	Building energy use (kWh)	Months
Environmental impact rating (T CO_2/ m²/year)	Ratio $kgCO_2$/kWh for electricity and gas	Electrical consumption from utility (kWh) Building Gas consumption (m³)	Yearly Yearly
Building energy use (kWh)	Conversion factor from m³ to kWh	Building electrical consumptions (kWh) Building gas consumptions (m³)	Months
Building gas consumption (m³)		Building electrical consumptions (kWh) Building gas consumptions (m³)	Months
Building electrical consumption (kWh)		Electrical consumption from utility Photovoltaïc production (kWh)	Months
Building electrical peak demand (kW)		Building electrical demand (kW)	10 mn
Heating (kWh/m²/ HDD and CDD)	Gross floor area (m²)	Heating consumption (kWh) Outdoor temperatures (°C)	10 mn 10 mn
Cooling (kWh/m²/ HDD and CDD)	Gross floor area (m²)	Cooling consumption (kWh) Outdoor temperatures (°C)	10 mn 10 mn
Domestic Hot Water system efficiency (%)		DHW production DHW load	Months Months
DHW energy use (kWh)	Conversion factor from m³ to kWh	Boiler gas consumption (m³)	Months Months
DHW load (kWh)		Boiler production (kWh)	Months Months
…	…	…	…

The recording frequency depends on the project objectives:

- For energy usage analysis or energy consumption alarming: measurement each 10’ or 15’ is necessary to get the load curve
- For energy sub-billing or bill auditing: the recording frequency shall be compatible with the tariff structure (once a day could be enough for constant tariff but not sufficient for several tariff slots per day)
- For cost allocation or building energy performance benchmarking: once a day is enough.

4.3.2 Method of measurement and meters locations

The above dynamic data lead then to identify the Point of Measurement in the building by selecting the method of measurement and the meters location. Especially for existing building, practicality of measurement should be verified according to the utilities distribution (electrical architecture and wirings, possibility to separate lighting and small power consumptions, gas distribution, accessibility to water meter, ..) and possible physical locations.

4.3.2.1 Methods of consumption measurement

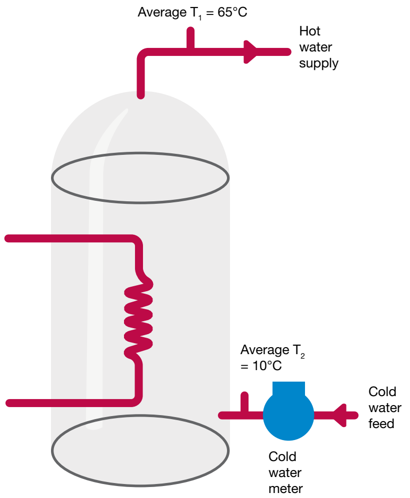
There are different methods to measure consumptions, described in the CIBSE guide GIL 65 “Metering energy use in new non domestic buildings” [7]. We tried to complete this list and to describe when each method is relevant or not.
The method of measurement shall be selected according to the project goals (especially the desired accuracy), the estimate budget and the operation conditions. The result of this step is the list of necessary meters to be installed in the building.

Electromechanical counter

- **Direct metering:** measure directly the consumption trough electric power meters, gas meters, oil meters, heat meters or steam meters…
Direct metering shall be selected in the followings cases:
- For loads of major consumptions or total building consumptions.
- When the measure is used for sub-billing for tenant areas as it requires a class 1 or 0,5 accuracy.
- When other data such as electric power quality data have to be measured for the same energy use. That the reason why disturbing loads or interruption sensitive loads shall be identified at a very early stage when designing the metering system.

- **Hours run meter:** for load of type constant power, measuring the number of operating hours enables to compute the corresponding consumption (ex: fans without VVD, lighting, …). Knowing the rating power indicated on the equipment plate is not always sufficient as the load factor has to be taken into account to estimate correctly the consumption. For existing buildings, the load factor can be known with a power measurement trough a portable meter.
As soon as there is load control (eg lighting control with occupancy sensor), it becomes very difficult to estimate the load factor and this method is no more valid.

- **Indirect metering:** readings from indirect meters can be used to evaluate energy consumption such as the example below:

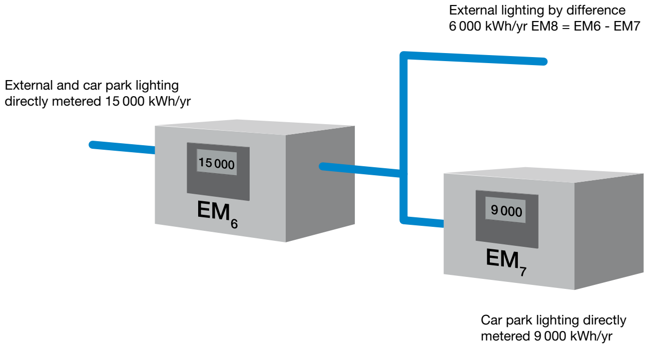


$$\text{Estimated consumption} = \frac{\text{metered feed water (litres/yr)} \times \text{Temp Diff (T1 - T2)} \times 4.185}{\text{boiler efficiency } 75\% \times 3600}$$

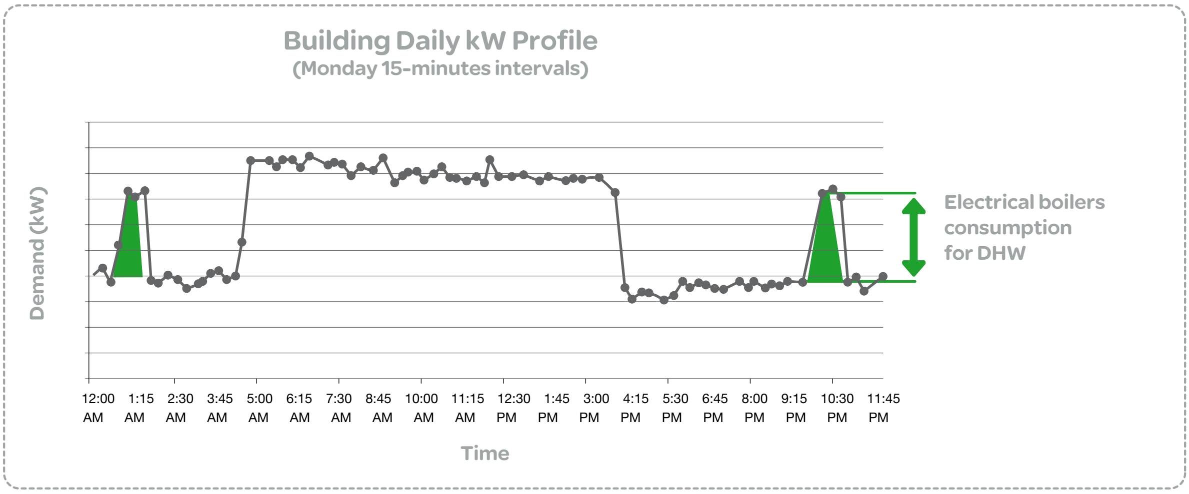
$$= \frac{844,\ 574 \times (65 - 10) \times 4.185}{0.75 \times 3600} = 72{,}000 \text{ kWh/yr}$$

Most of the time, estimation accuracy depends on the equipment data (such as the boiler efficiency here above) that can change or evolve with time, therefore these data have to be checked regularly.

- **By difference:** Two direct metering can be used to determine a third measurement by difference. Such method should only be used if the two others measurements are acquired trough direct metering. This method should not be used if a small consumption is substracted from a large one, because the accuracy margin could be higher than the small consumption.



- **By data analysis**: It is possible with one measurement to break down different energy uses or area consumptions by knowing how the building operates. For example in a hotel, knowing that during the night most of the electrical consumption in the floors is of type common use (corridor lighting…), the electrical consumptions of the floor during this time slot represents the consumption of the common area. Therefore, metering the feeder of the floor panel board is sufficient instead of installing additional meters. The chart below shows the identification of electrical boilers consumption during the night by metering only the whole building load profile.



- **Estimation:** Calculations can be used to estimate consumptions of small power loads thanks to ratio (e.g. kWh/m²) given in some standards or by knowing the occupant behavior. For example, plug-in lighting consumption can be estimated trough number, power rating and scheduled of lamps.

4.3.2.2 Locations

Location of the meter is determined according to what energy flow they need to measure in the schematic diagram but other criteria should also be taken into account such as:

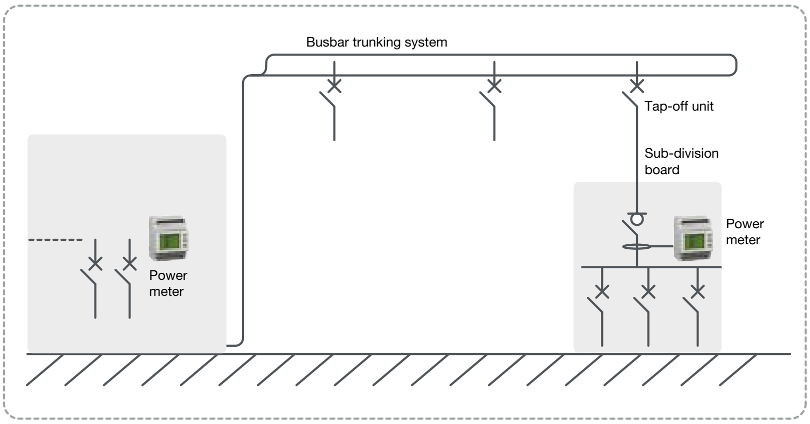
- Practicality of the measurement
- Needs of local visualization: meters shall be placed so that they can be read easily by the building operator. Typically this will be the plant room, main distribution room or control room
- The possibility to re-use existing meters.

Special consideration for electrical meter location

1. Feeder or incoming instrumentation for electrical switchboard

For electrical meters, it is generally advisable to instrument the feeders of the main LV switchboard instead of the incomers of the sub-distribution switchboards in order to:
- Reduce the lengths of communication cables
- Get an overview of consumptions of all feeders of the Main LV switchboard in the switchboard room
- Use protection devices that embed metering. It will avoid external meter and CT installation, reduce cabling and increase switchboard spare capacity.

However, some reasons can lead to instrument the incomer of a sub-distribution switchboard such as:
- The lack of room in the main switchboard for existing buildings
- Multi tenant building with sub-billing. The meters should then be installed in each floor/tenant panelboard, so that the tenant can have access to this meter.
- An electrical distribution with Busbar Trunking System in order to get an easy access to the meters and generally because of lack of room in the tap-off unit.



2. Integrated or independent metering panelboard

The metering devices can be installed inside the switchboard or in an external metering panelboard when it is requested or when space is limited in the switchboard for existing buildings. This can have an impact on the type of meter to select (embedded or separated metering).

4.3.3 Synthesis table

A the end of the step “define point of measurement”, the following table should be completed.

		Necessary data to build the performance metrics		Point of Measurement			
	Performance metrics	Static data	Dynamic data	Recording frequency	Measurement method	Meters	Location
1	Building energy use intensity (kWh/m^2)	Gross floor area (m^2)	Building energy use (kWh)	Months	Use 3	N/A	N/A
2	Environmental impact rating (T CO$_2$/ m^2/year)	Ratio kg CO$_2$/kW	Electrical consumption from utility (kWh)	Yearly	Use 5	N/A	N/A
			Building Gas consumption (m^3)	Yearly	Use 4	N/A	N/A
3	Building energy use (kWh)	Conversion factor from m^3 to kWh	Building electrical consumptions (kWh)	Months	Use 5	N/A	N/A
			Building gas consumptions (m^3)	Months	Use 4	N/A	N/A
4	Building gas consumption (m^3)		Building gas consumption (m^3)	Months	Direct metering	Main gas meter	Outdoor
5	Building electrical consumption (kWh)		Electrical consumption from utility	Months	Direct metering	Main electrical meter	Main electrical room
			Photovoltaïc production (kWh)		Direct metering	Energy meter	Main electrical room
6	Building electrical peak demand (kW)		Building electrical demand (kW)	10 mn	Direct metering	Main electrical meter	Main electrical room
7	Heating (kWh/m^2/HDD and CDD)	Gross floor area (m^2)	Cooling consumption (kWh)	10mn	Direct metering	Gas sub-meter for boiler	Boiler room
			Outdoor temperatures (°C)	10mn	Direct metering	Temperature probe	Outdoor (North)
8	Cooling (kWh/m^2/HDD and CDD)	Gross floor area (m^2)	Cooling consumption (kWh)	10mn	Direct metering	Chiller electrical meter	Main electrical room
			Outdoor temperatures (°C)	10mn	Direct metering	Temperature probe	Outdoor (North)
9	Domestic Hot Water system efficiency (%)		DHW energy use DHW load	Months	Use 10 and 11	N/A	N/A
10	DHW energy use (kWh)	Conversion factor from m^3 to kWh	Boiler gas consumption (m^3)	Months	Direct metering	Gas sub-meter for boiler	Boiler room
11	DHW load (kWh)		Boiler production (kWh)	Months	Indirect metering	Cold water flow meter Temperature probes (supply & return)	Months
12	…	…	…	…			

4.3.4 Usual point of measurement per energy use

We propose here below some guideline to define the points of measurement according to the energy use and the required granulometry of the measurement (building global consumption, consumption per floor or area).

4.3.4.1 Lighting

Data to collect according to granulometry of consumption:

- Global consumptions: aggregations of lighting consumptions of each area
- Area consumptions: consumption of the circuits supplying the area – it includes energy consumed by lighting fixtures, ballast, transformers…

Method of measurement:

- Without individual control or dimming: hours counter or electrical meter
- With control or dimming: electrical meter.

Point of measurement locations:

- Lighting feeders or group of feeders in the electrical switchboards.

4.3.4.2 Ventilation

For mechanical ventilation, fans are the main consumers.

Data to collect according to granulometry of consumption:

- Global consumptions: aggregations of each fans consumptions
- Area consumptions: calculations according to m^2 ratio
- Nb of starts and stops.

Method of measurement:

- Without Variable Speed Drive: hours counter or electrical meter
- With Variable Speed Drive: electrical meter or embedded meter in the VSD.

Point of measurement locations:

- Fans feeders, group of fans feeders or VSD in the main electrical switchboards or HVAC switchboards.

4.3.4.3 Heating & Cooling

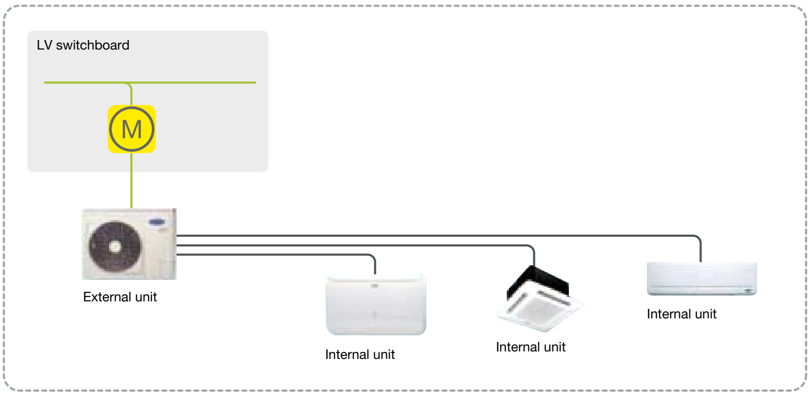
This energy use is the major consumer in tertiary building, there fore it is strongly advisable to use direct metering to achieve a satisfying accuracy. For a description of each Heating and cooling system, refer to the document [1] "Office reference architectures" 3.1.1 A. Jammes

Legend

🟩 Electrical wiring system
🟥 Hot water pipe
🟦 Cold water pipe
⬛ Gas or floul pipe
Ⓜ Point of measurement

4.3.4.3.1 Refrigerant fluid – Split and Multi-split systems

The external unit is supplied from the LV switchboard and it supplies wall internal units.



Data to collect according to granulometry of consumption:

- Global consumptions: aggregations of each split system consumptions
- Area consumptions: consumptions of the corresponding split system which includes internal units and external unit consumptions.

Method of measurement:

- Direct metering: electrical meter.

Point of measurement locations:

- Feeders in the main electrical switchboards for small buildings or floor/tenant panelboard for large buildings.

Breakdown between Heating and Cooling:

- Some split system can be inverters. In order to break down the heating and cooling consumptions, an additional measurement should indicate the mode of operation, such as:

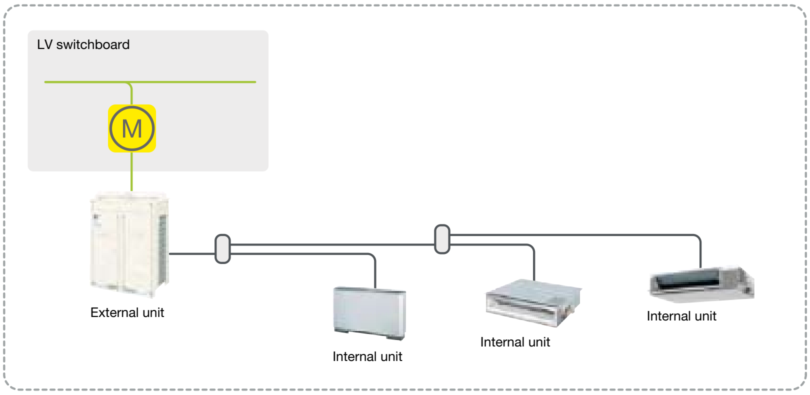
- Control signal
- Measurement of the supply and return fluid temperatures.

4.3.4.3.2 Refrigerant fluid – VRF/VRV (Variable Refrigerant Flow/Volume)

The external unit is supplied from the LV switchboard and it supplies all internal units.

Principle

Electrical diagram



Data to collect according to granulometry of consumption:

- Global consumptions: aggregations of each VRF system consumptions
- Area consumptions: consumptions of the corresponding VRF system which includes internal units and external unit consumptions.

Method of measurement:

- Direct metering: electrical meter.

Point of measurement locations:

- Feeders in the main electrical switchboards or floor/tenant panelboard.

Breakdown between Heating and Cooling:

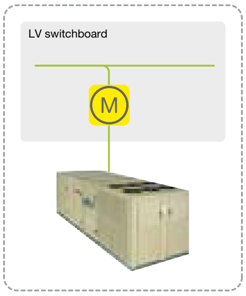
Two kinds of VRF exist:

- 2 pipes: all terminal unit heat or cool at the same time. In order to break down the heating and cooling consumptions, an additional measurement should indicate the mode of operation, such as:
  - Control signal
  - Measurement of the supply and return fluid temperatures (at the outdoor unit level)
- 3 pipes : each terminal unit are independents. Some unit may heat while another one may cool at the same time. The breakdown is therefore very difficult to realize. (to be investigated).

4.3.4.3.3 Air system – Rooftop

The rooftop is supplied directly from a LV switchboard.
The air distribution in the duct system is provided by the rooftop.

Electrical diagram



Data to collect according to granulometry of consumption:
This system is normally used for a large open space area such as supermarket sale areas.

- Global consumptions: aggregations of each rooftop consumptions
- Area consumptions: possible if the rooftop is used for a dedicated area otherwise it is not possible to make an area breakdown.

Method of measurement:

- Direct metering: electrical meter.

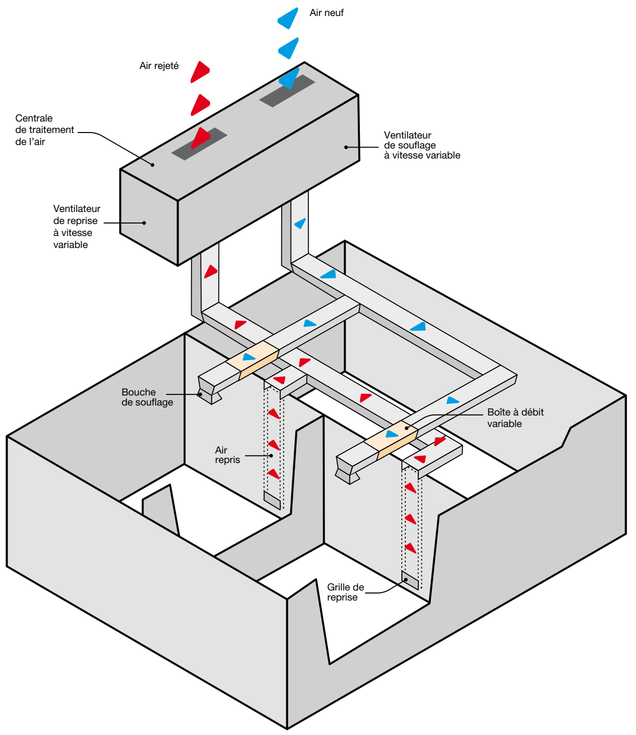
Point of measurement locations:

- Feeders in the main electrical switchboards or HVAC switchboard.

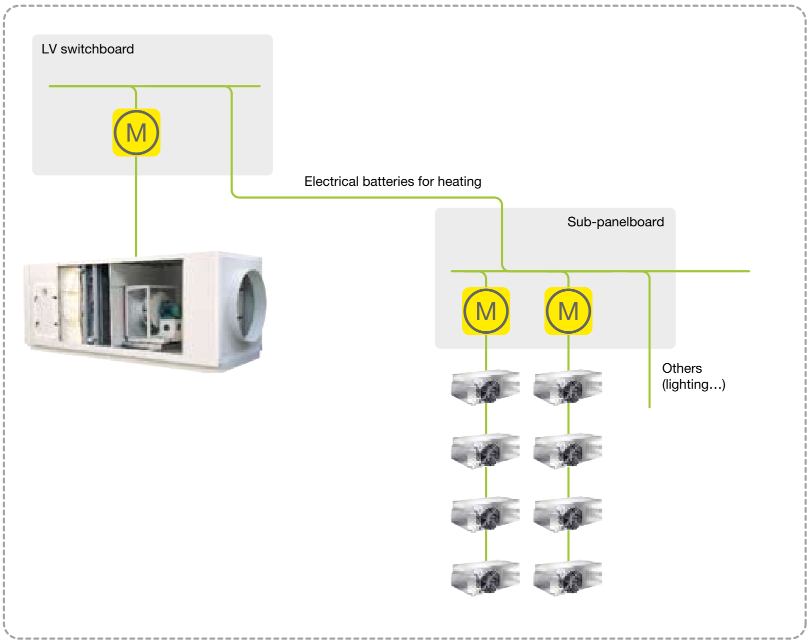
Breakdown between Heating and Cooling:
The rooftop provides most of the time only cooling.

4.3.4.3.4 Air system – VAV (Variable Air Volume)

Principle



Electrical Diagram



Data to collect according to granulometry of consumption:

- Global consumptions:

- AHU consumption
- Electrical batteries consumptions for electrical heating
- Boiler consumption for hot water production and pumps consumption for distribution.

- Area consumptions: possible if the AHU is used for a dedicated area otherwise it is not possible to make an area breakdown.

Method of measurement:

- Direct metering: electrical meter.

Point of measurement locations:

- Feeders in the main electrical switchboards or HVAC switchboard.

Breakdown between Heating and Cooling:

We assume that cooling is provided by the AHU. Heating can be provided either by :

- Electrical battery in each VAV terminal unit – then the consumptions of heating has to be metered in each sub-panelboard (floor or area)

or

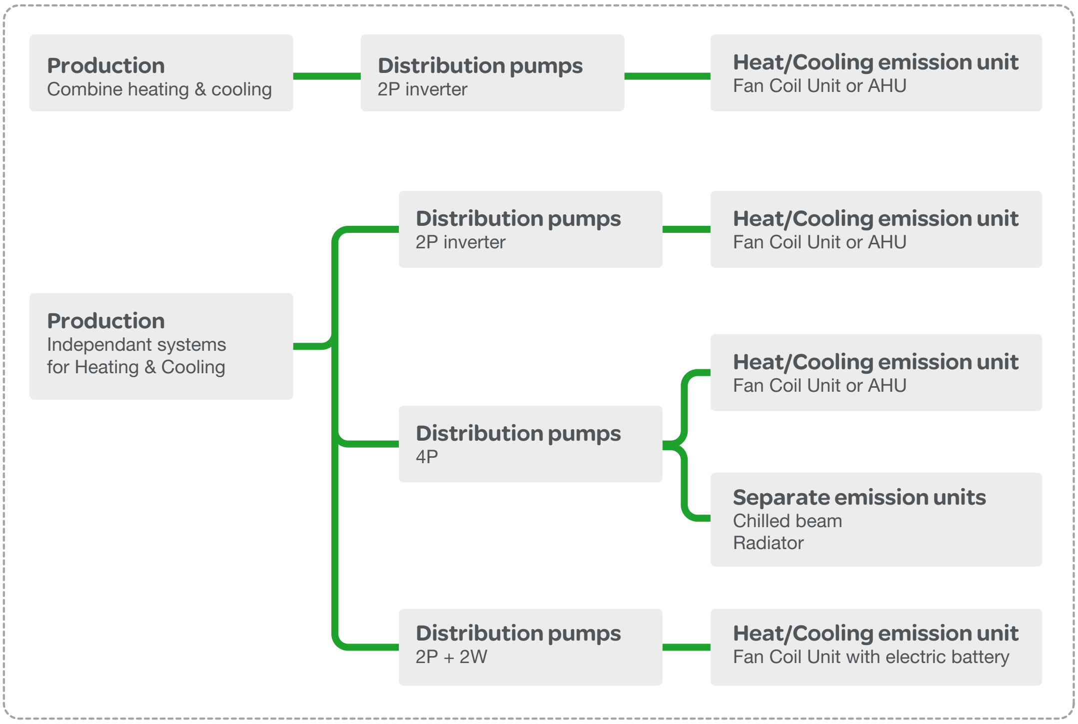
- Hot water battery from a central boiler – heating consumptions has to be metered from the central heating boiler with an heat meter.

4.3.4.3.5 Water system

In the case of a two pipes system only heating or cooling is possible at the same time in the building (2P inverter).

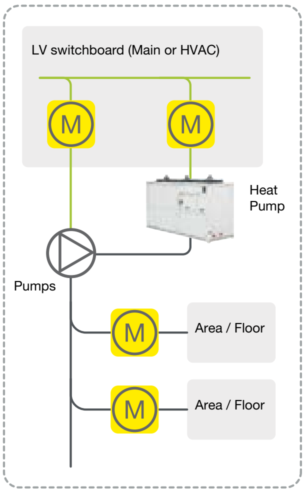
In the case of a four pipes system cooling and heating can happen simultaneously (4P). This is the same for a two pipes and two wires system (2P+2W).

The picture here below describes the different elements of the system:



4.3.4.3.5.1 Combine heating and cooling – 2 P inverter

Typical systems of type combine heating and cooling are reversible heat pumps.



Data to collect according to granulometry of consumption:

- Global heating and cooling production:
- Boiler(s) gas consumption
- Chiller(s) electrical consumption
- Global heating and cooling distribution:
- Pumps electrical consumption
- Area consumptions: heating and cooling consumptions of the dedicated area

Method of measurement

> Heat pump consumption

- Direct metering: electrical meter

> Pump distribution consumption

- Direct metering: electrical meter or embedded meter in the VSD

> Area consumption

- Direct metering: heat-cold meter, such meter is able to split heating and cooling consumption.

Point of measurement locations:

- Heat pump and pumps consumptions: feeders in the main electrical switchboards or HVAC switchboard
- Area consumptions: after the area pipe derivation, but location may strongly depends on the water distribution.

Breakdown between Heating and Cooling:

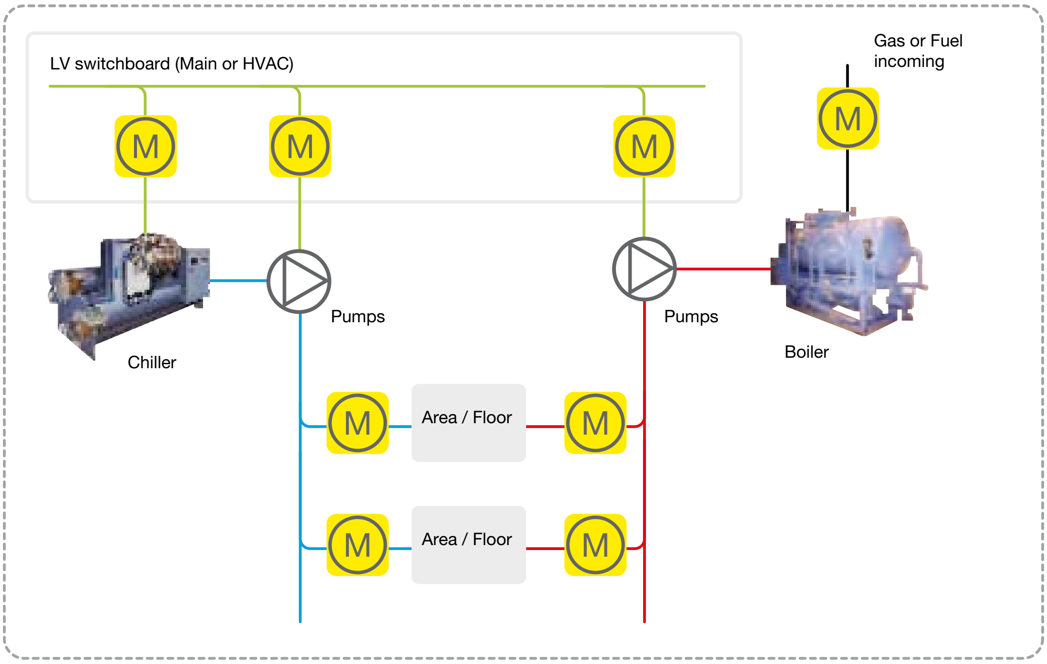
Global consumption: the solutions to break down heating and cooling are:

- Use of heat-cold meter at the heat pump level – this may require a communication interface (M-Bus, RS485, …) instead of pulse communication
- Control signal from the heat pump controller
- Measurement of the supply and return water temperatures.

Area consumption: the solutions to break down heating and cooling at this level are:

- Use of heat-cold meter at the heat pump level – this may require a communication interface (M-Bus, RS485, …) instead of pulse communication.

4.3.4.3.5.2 Independent systems for heating and cooling – 4 P



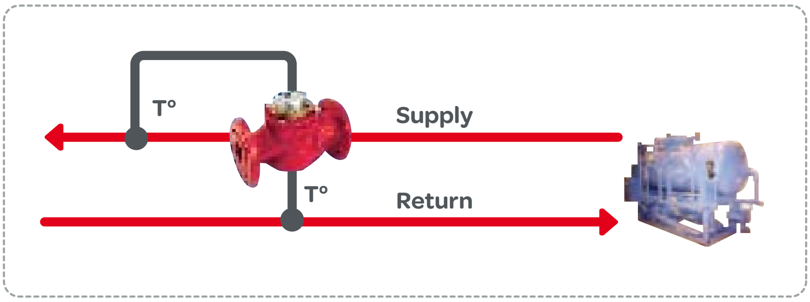
Data to collect according to granulometry of consumption:

- Global heating and cooling production:
- Boiler(s) gas consumption
- Chiller(s) electrical consumption
- Global heating and cooling distribution:
- Pumps electrical consumption
- Area consumptions: heating and cooling consumptions of the dedicated area

Method of measurement

> Boiler consumption

- Direct metering: gas or fuel meter
- Indirect metering: heat meter - boiler efficiency shall be taken into account (% or m3/kWh).



Gas consumption for heating
= heat meter consumption (kWh) x boiler efficiency (m^3/kWh)
(ratio kWh/m^3 is around 11 for natural gas)

Remark

Measuring both incoming gas consumption and heating production with an heat meter enables to check the boiler efficiency that can evolve with time.

> Chiller consumption

- Direct metering: electrical meter.

> Pump distribution consumption

- Direct metering: electrical meter or embedded meter in the VSD.

> Area consumption

- Direct metering: heat and cold meters.

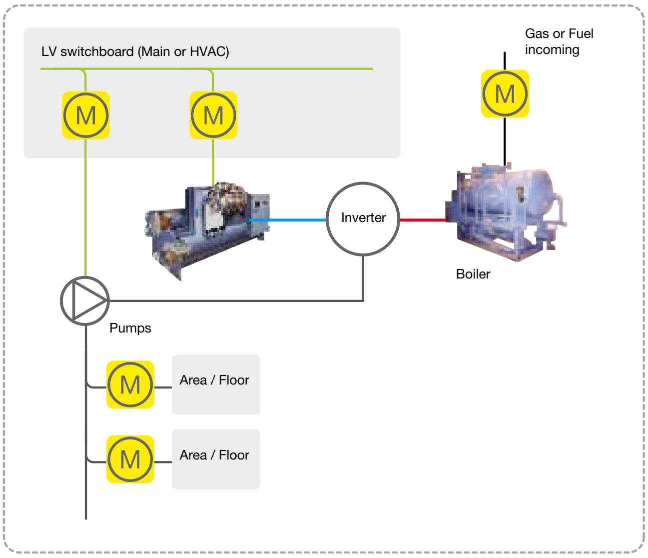
Point of measurement locations:

- Chiller and pumps consumptions: feeders in the main electrical switchboards or HVAC switchboard
- Gas consumption for boiler: utility meter location or boiler room
- Area consumptions: after the area pipe derivation, but location may strongly depends on the water distribution.

Breakdown between Heating and Cooling:

With a 4P distribution, heating and cooling are naturally independent.

4.3.4.3.5.3 Independent systems for heating and cooling – 2 P inverter



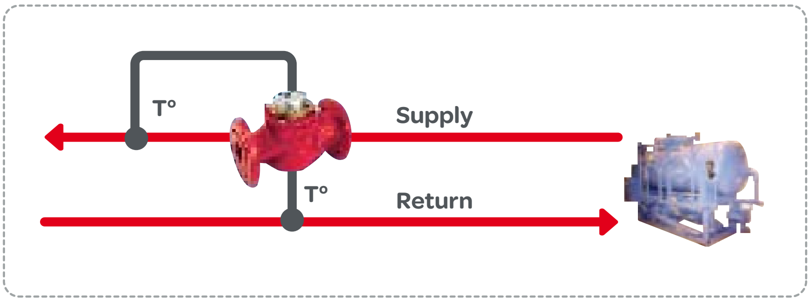
Data to collect according to granulometry of consumption:

- Global heating and cooling production:
- Boiler(s) gas consumption
- Chiller(s) electrical consumption
- Global heating and cooling distribution:
- Pumps electrical consumption
- Area consumptions: heating and cooling consumptions of the dedicated area.

Method of measurement:

> Boiler consumption

- Direct metering: gas or fuel meter
- Indirect metering: heat meter - boiler efficiency shall be taken into account (% or m3/kWh).



Gas consumption for heating
= heat meter consumption (kWh) x boiler efficiency (m^3/kWh)
(ratio kWh/m^3 is around 11 for natural gas)

Remark

Measuring both incoming gas consumption and heating production with an heat meter enables to check the boiler efficiency that can evolve with time.

> Chiller consumption

- Direct metering: electrical meter.

> Pump distribution consumption

- Direct metering: electrical meter or embedded meter in the VSD.

> Area consumption

- Direct metering: heat-cold meter, such meter is able to split heating and cooling consumption.

Point of measurement locations:

- Chiller and pumps consumptions: feeders in the main electrical switchboards or HVAC switchboard
- Gas consumption for boiler: utility meter location or boiler room
- Area consumptions: after the area pipe derivation, but location may strongly depends on the water distribution.

Breakdown between Heating and Cooling:

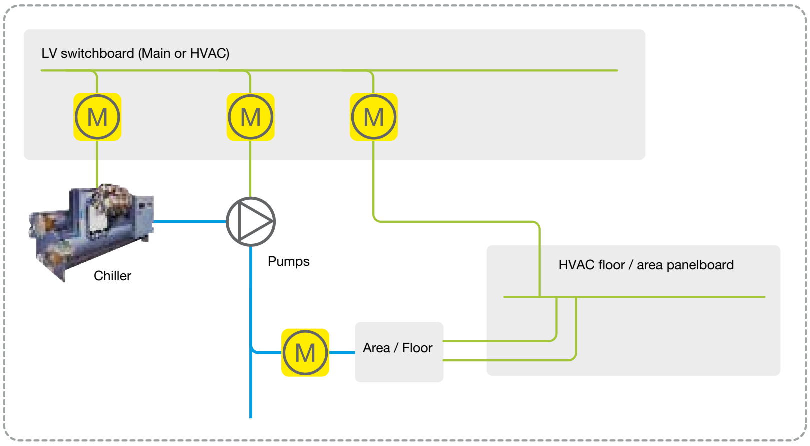
Global consumption: heating and cooling productions are independent.
Area consumption: the solutions to break down heating and cooling at this level are:

- Use of heat-cold meter – this may require a communication interface (M-Bus, RS485…) instead of pulse communication
- The cooling or heating mode can also be given by the operator himself in the data analysis system.

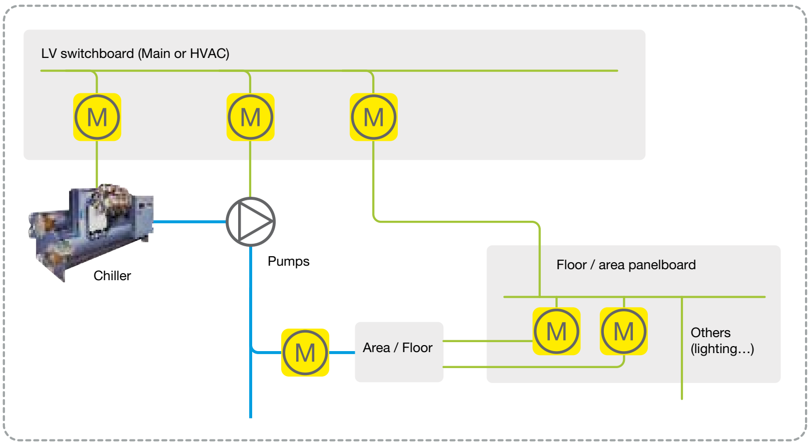
4.3.4.3.5.4 Independent systems for heating and cooling – 2P+2W

The location of the point of measurement for heating depends on either there are electrical independent floor HVAC panel boards or floor panel boards that mix lighting, HVAC and office equipment.

Independent HVAC floor panel



Non independent HVAC floor panelboard



Data to collect according to granulometry of consumption:

- Global cooling: chiller(s) electrical consumption
- Global cooling distribution: pumps electrical consumption
- Global heating: aggregations of electrical batteries consumptions of each area
- Area consumptions:

- Heating: electrical batteries consumptions of the dedicated area
- Cooling: cooling consumption of the dedicate area.

Method of measurement:

> Electrical batteries consumption

- Direct metering: electrical meter.

> Chiller consumption

- Direct metering: electrical meter.

> Pump distribution consumption

- Direct metering: electrical meter or embedded meter in the VSD.

> Area consumption

- Direct metering: electrical meter for heating.

Point of measurement locations:

- Chiller and pumps consumptions: feeders in the main electrical switchboards or HVAC switchboard
- Electrical battery consumptions:

- Independent HVAC floor panelboard: feeders in the main electrical switchboards or HVAC switchboard
- Multi energy use floor panelboard: feeders in the main electrical switchboards or HVAC switchboard

- Area consumptions: cold meters have to be installed at the floor level in the technical room.

Breakdown between Heating and Cooling:

Heating and cooling productions are independent.

Remark

Electrical batteries in FCU can sometimes be used as booster and combined with a central water heating. Point of measurement for heating shall then be added according to the type of production (combine or independent) in the corresponding paragraphs.

4.3.4.4 Domestic Hot Water

We need to consider:

- DHW production: primary energy that is necessary to heat the water
- DHW load: thermal energy delivered to the distribution system – it represents the need for DHW.

These 2 values are linked by the following equation:
DHW production = heating system efficiency x DHW load.

The heating system efficiency takes into account the boiler efficiency and the losses in the hot water storage tank.

4.3.4.4.1 Independent electrical boiler

Data to collect according to granulometry of consumption:
> **Global consumptions:** aggregations of electrical boiler consumptions of each area
> **Area consumptions:** consumption of the boiler feeder.

Method of measurement:

- Direct metering: electrical meter.

Point of measurement locations:

- Feeders in the sub-electrical switchboards.

Remark

Hours counter is not possible as most of the boiler integrate their own control

4.3.4.4.2 Independent central gas boiler

Data to collect according to granulometry of consumption:

- Global consumptions: gas boiler consumption and pumps consumption
- Area consumptions: difference of the supply and return flow of the dedicated area.

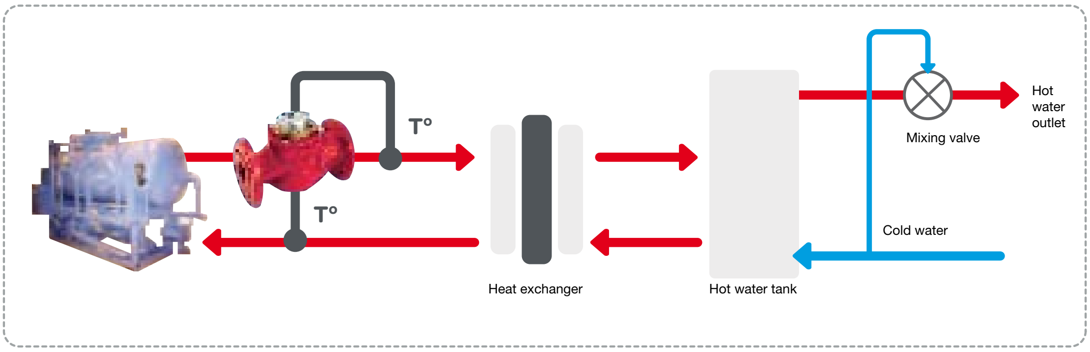
Method of measurement:
> **Boiler consumption:**

- Direct metering: gas meter
- Indirect metering:

- Solution 1: heat meter at the primary circuit – boiler efficiency has then to be taken into account to calculate the primary energy.

Remark

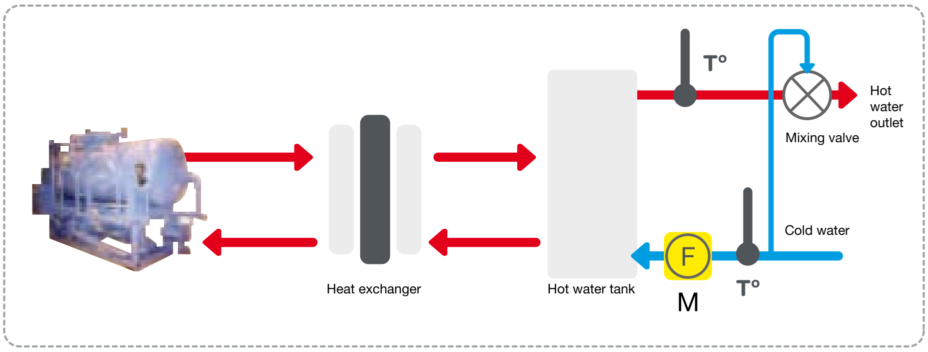
Recirculation may or may not be present in the system



- Solution 2: in existing building, it is usual that hot water temperature (shall be above 50°C to avoid legionella problems), cold water temperature and cold water flow (leakage detection) are already metered downstream the hot water tank. It is then possible to calculate the DHW load with the following formula.

$$Q = \int_{v2}^{v1} k\,(t1 - t2)\,dV$$

The heating system efficiency has then to be estimated in order to calculate the primary energy used for hot water heating.



> Pumps consumptions:
- Direct metering: electrical meter.

> Area consumption:
- Direct metering: use of a flow meter at the pipe derivation
- Indirect metering: measure the hot pipe temperature of the corresponding area. Each time a run-off is observed, the temperature rise in the pipe of the area that consumes. The corresponding water consumption and energy consumption metered at global level can then be allocated to the area.

This method is only valid if the consumption of each area is separated in time, for instance this is not possible for a hotel.

Point of measurement locations:
- Boiler consumption: boiler room

> Area consumption:
- After the pipe derivation, but location may strongly depends on the water distribution.

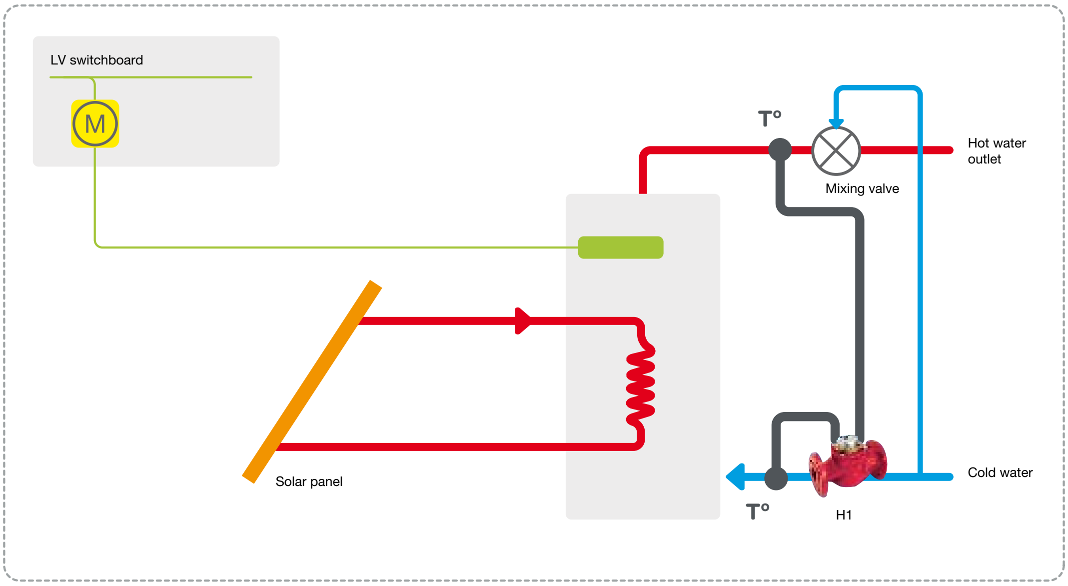
4.3.4.4.3 Combine with space heating

Only indirect metering allows then to split space heating from DHW production. The solutions described in the previous paragraph can then be used but heat meter shall be installed on the DHW distribution pipe system.

4.3.4.4.4 Solar heating

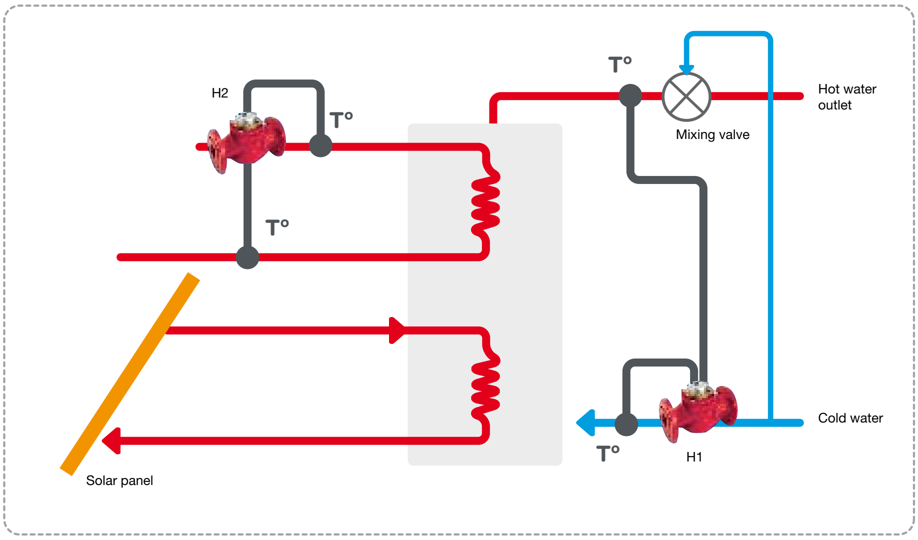
Some labels or standards require measuring separately renewable production, to be able to split the DHW produced by solar heating from those produced by heating booster, the following points of measurement shall be considered.

4.3.4.4.4.1 With electrical booster



DHW load = Heat meter H1 data (kWh)
DHW production = Electrical meter data (kWh)
Solar production = DHW load x heat tank efficiency (%) – DHW production

4.3.4.4.4.2 With boiler booster



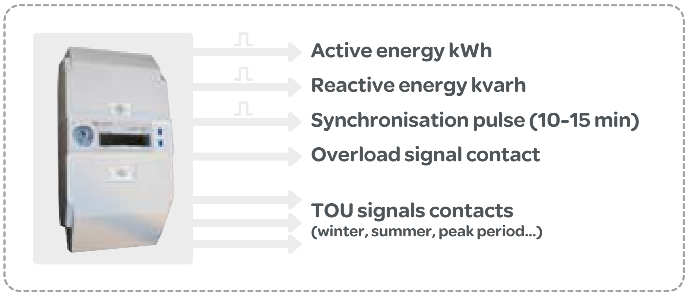
DHW load = Heat meter H1 data (kWh)
DHW production = Heat meter H2 (kWh) / gas boiler efficiency (%)
Solar production = DHW load x heat tank efficiency (%) – Heat meter H2 (kWh)

4.4 Re using existing main meters

4.4.1 Main electrical meters

Following data may be available from the main electricity meter:
- Active energy for the whole facility
- Reactive energy for the whole facility
- Time Of Use signals to be able to estimate electricity bill and benefit from low rate periods
- Billing base synchronization (typically each 10 or 15 mn)
- Overload signal.

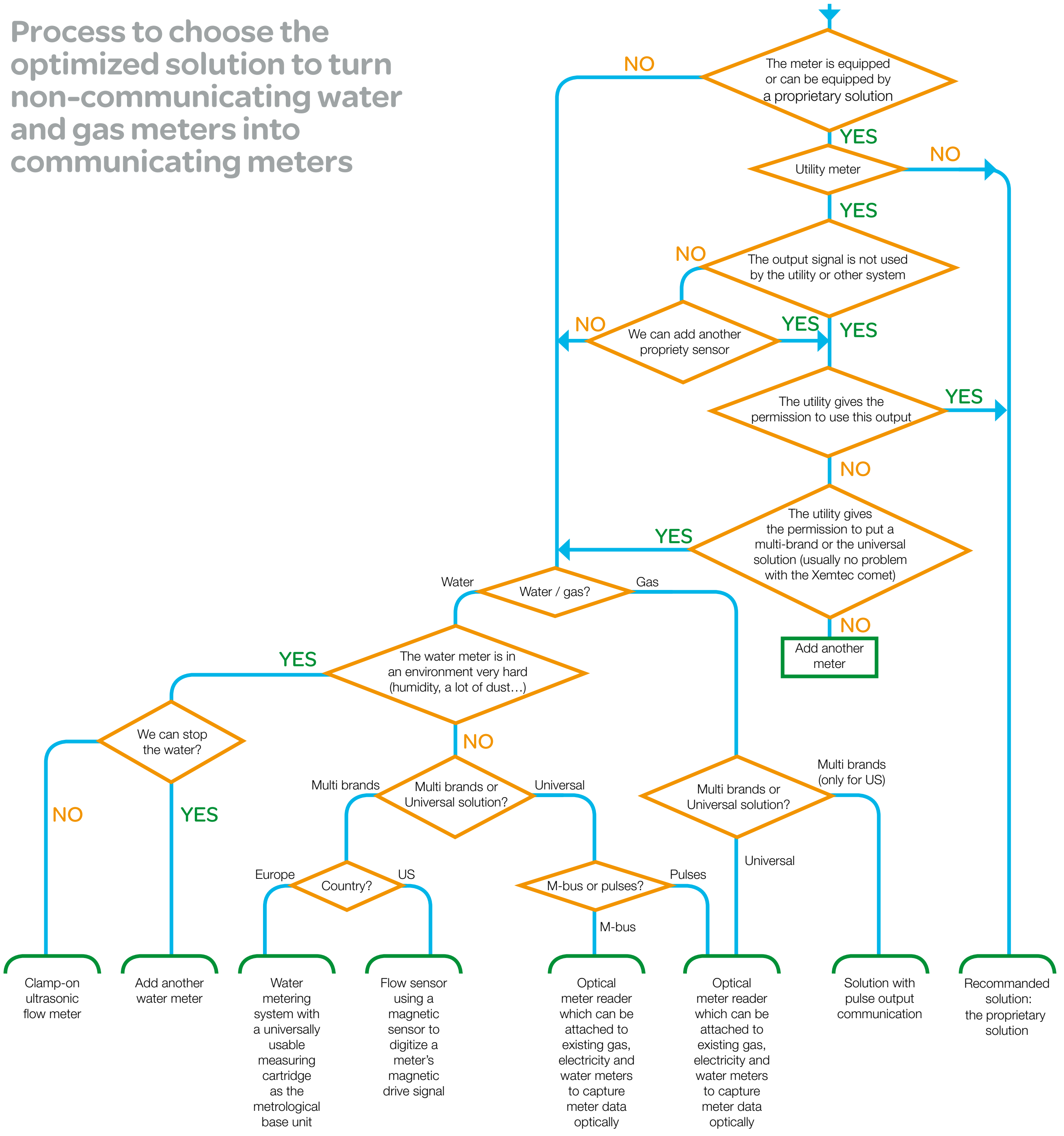
Most of the time, there are pulse or contact outputs on the meter to collect these data, if not a new incoming meter shall be installed.



4.4.2 Water and gas meters

Collect data from existing water and gas meters (Emmanuel & Stan’s document).

Process to choose the optimized solution to turn non-communicating water and gas meters into communicating meters



For more information on communicating water and gas meters, please refer to Schneider Electric “Water and gas meters recommendations guide”.

4.5 Selecting additional meters

4.5.1 Electrical meters

Calculating energy consumption requires voltage and current measurements. A lot of other parameters that may not be part of energy management but important for the building operator are based on these two values. Therefore, we shall also consider these parameters when selecting an electrical meter as they are most of the time accessible from the same meter.

4.5.1.1 Criteria

The meters have different characteristics according to the project goals; we give here below a description of the main criteria that can help to select the type of meters.

4.5.1.1.1 Data for energy management

Two types of meters can be considered according to the data they are able to measure:

- Energy meter
- Power meter.

The first category is used for basic energy management as they enable to measure kWh with optional communication output.

The second category enables to measure active and reactive energy consumptions but also a wide range of data (depending on the device) such as:

- Four quadrant especially for local energy production
- The power factor
- The apparent power
- The demand for active and reactive power
- Overload alarm on active power demand
- Save active power demand
- Peak power demand
- Poad profile.

4.5.1.1.2 Data for electrical distribution monitoring: Installation monitoring or power quality measurement

These data give a better understanding of how the electrical distribution works and help the maintenance team to avoid failures or restore power as quickly as possible.
Depending on the criticality of the process, the metering device shall be able to give and report some of these data.

Some applications in a building require installation monitoring or power quality features such as:

- Cold generator in an Hypermarket: alarming when powercut
- Sensitive loads as IT server: harmonic issues lead to monitor and analyze these disturbances to avoid nuisance tripping and separate harmonics sources from these loads.

Data necessary for Installation monitoring and PQ measurement are:

- Switchgear status
- Electrical parameters with max and min values (voltage, current, power)
- Alarms and event time stamp of electrical parameters
- Harmonics monitoring.

If the installation requires data for predictive maintenance (number of operations, level of wear…) circuit-breakers such as NSX or Masterpact with the appropriate trip unit (Micrologic E) is a good solution if the features for energy metering are sufficient.

4.5.1.1.3 Requirement for specific application such as sub-billing or shadow metering

Application such as sub-billing or shadow metering requires specific characteristics.

Sub-billing:

- Accuracy: class 1 or 0.5
- Depending on countries: mechanical and settings lock capability.

Shadow metering:

- Accuracy: identical to the utility meter i.e at least class 0.2.

These meters are of type advanced energy metering.

4.5.1.1.4 Local or remote reading

All meters enable to read locally the data thanks to a graphical display.
This helps the operation manager to get the data at the right location.
For several reasons such as the number of data to collect or the need to get a permanent monitoring of the consumption the metering device has to be equipped with a communication output. The type of communication is also a criterion to select the device and could be of type:

- Pulse – they have to be integrated in a “pulse concentrator” (dedicated product or PLC) which converts these pulses in an energy data and stores these data in a local data-log. The recording frequency has also to be taken into account (see § 5.1.1 what are the data to collect?) as the number of pulse per kWh may differ from one device to another.

- Communication protocol such as Modbus, ethernet or M-Bus.

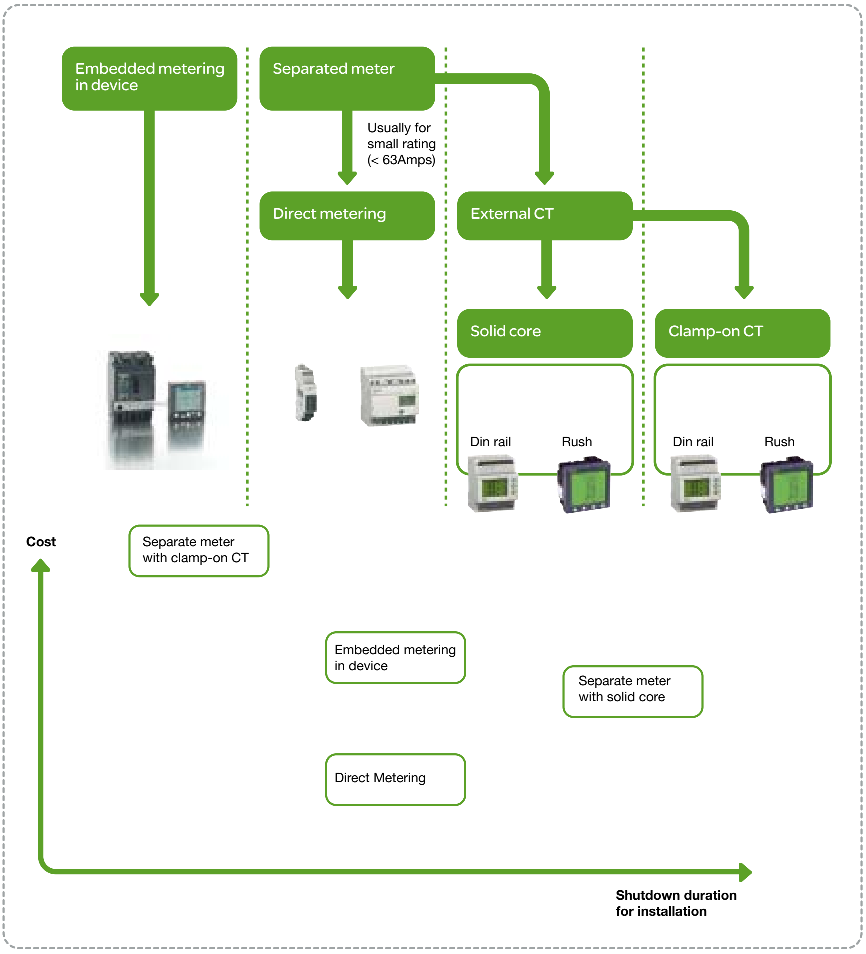
The data are then transferred to an EMS (Energy Management System) or BMS (Building Management System) to be aggregated, normalized and analyzed.

4.5.1.1.5 Installation mode and shut down time

Especially for existing buildings, the installation and shut down time can be very high due to the difficulty to install current transformers (CT) or due to limited space in the switchboard, this shall be considered to select the following characteristics of the metering devices and installation mode:

- Embedded or separate metering
- Direct metering or external CTs
- Clamped on CTs
- Flush or din rail.

These characteristics are linked as below:



Embedded or separate metering

More and more devices installed in building infrastructure embed electronics with communication capability. As soon as their core function needs current metering, they are able to calculate energy consumption data.

Compared to independent Meters, these devices don't require additional external CT's. In general, these CT's (and VT's in some cases) have been chosen for the characteristics of their core function, protection for example. Accuracy of metering of such devices is generally not as good as the accuracy of power meters, not enough for advanced features.

Some examples of Schneider Electric devices

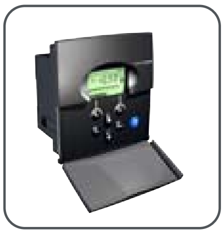
Circuit breakers with electronic trip units

Compact NSX equipped with Micrologic-E trip unit

Speed drives

Altivar 21

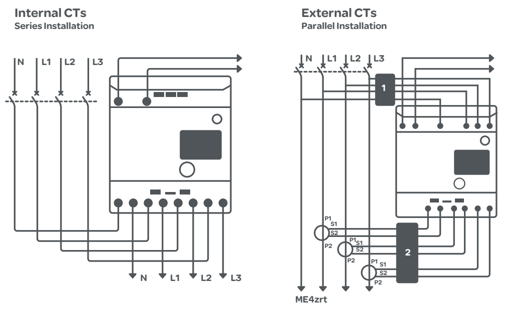
Varmeter controllers



Varlogic-N

Direct measurement or external CTs

When the measurement is done with a separate meter, this meter can be equipped with internal CTs that will ease the installation in the switchboard, avoid CT cabling and meter protection and therefore reduce the installation time. Internal CTs are available for energy meter (only kWh) of type EN40 and ME up to 63A.



Split core current transformers

When continuity of service is required in a existing building, split core current transformers can be proposed. Use of such CT will avoid the circuit being measured to be disconnected and the wire threaded trough the CT opening, they work best in crowed electrical panel where space is often limited. These CTs cost more than solid core CT (five as expensive).

Solid core

Split core

Flush mounted or DIN rail

The installation of the meters in the switchboard can be of type:

- Flush mounted: the meter is installed on the front door of the switchboard. Access and visualization is easy for operation and maintenance team with cut-out in the door.
- Rail DIN: directly on the rail in the switchboard. This requires space in the switchboard and preferably a transparent door.

4.5.1.2 Main guidelines for a commercial site

The schemes and table here below give advices to select the right metering index according to the level in the electrical architecture, current ratings and the sensitivity of the load or feeder. Sensitive feeders need special attention in terms of power quality and electrical distribution monitoring.
However each project has to be studied particularly according to network configuration and customer needs.

4.5.1.2.1 Needs

The category of the metering device is generally linked to the level of the electrical distribution:

- Metering devices that are installed at the incoming of the electrical installation shall enable:

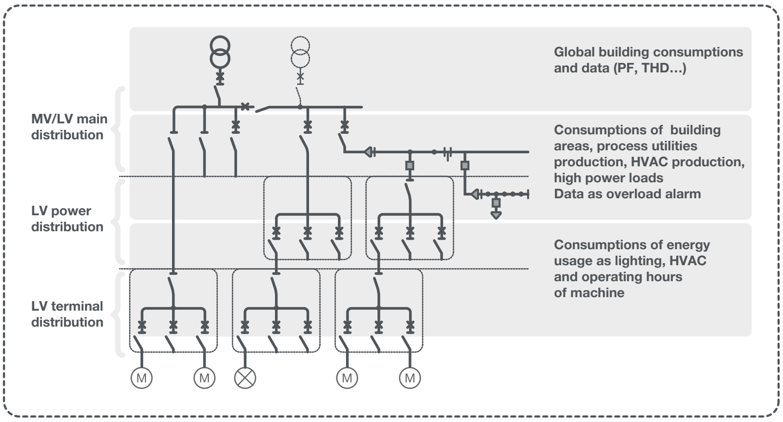
- To analyze the building power demand (load profile) and the peak demand (value and duration)
- To check the energy bill and penalties (reactive consumptions and overload)
- To analyze power quality such as harmonic distortion.

- Metering device that are installed at the feeder of the main low voltage switchboard (or at the incoming of sub-distribution switchboard) shall enable:

- To perform sub-metering (consumption monitoring of building areas or lines of process) for cost allocation
- To follow consumptions for building utilities such as Air Handling Unit, boilers, chillers or another major energy use for:
  > Energy usage analysis
  > Building benchmarking
  > Standard or labels certification
  > Building control optimization
  > To improve maintenance with alarms.

- Metering device that are installed at the final level shall enable:

- To perform an energy use breakdown as requested by some standard or labels certification or to enable building benchmarking
- To follow energy use consumptions for:
  > energy usage analysis
  > building regulations optimization
- To know the number of operating hours of a machine or motor for maintenance.



Main electrical incoming

- Rating current < 630 Amps

Metering devices that are installed at the incoming of the electrical installation shall collect common data for the whole installation:
- Global active and reactive energy consumptions with the global power factor
- Harmonic distortion (THD) to check the network power quality
- Overload alarming and min/max of Powers/ Voltage/ Current to follow global energy consumption and maintenance parameters.

- Rating current > 630 Amps

In addition to the previous requirements, it is advisable for this rating:
- To limit the uncertainty of the measurement by selecting a meter with 0,5 class accuracy and enable to check the energy bill
- To be able to perform event analysis for the maintenance team, it leads to select meter with event stamping
- To get the load profile and 10mn synchronization with the utility meter to optimize the contract
- In an hypermarket due to the significant part of lighting and IT, TV department, harmonic distortion could be high; detailed harmonics analysis shall be performed to determine the best filtering solution to reduce harmonics.

Renewable energy production

- Photovoltaic

A simple energy meter is sufficient to measure the energy production.

- Wind

When the wind speed is low, the generator can be used as motor (for example to help the blades start to turn). In this case, the wind turbine consumes energy; therefore it is advisable to select a meter with four quadrants to enable a breakdown between production and consumption.

Back-up generator production

When the back-up generator is used several hours a month due to bad utility reliability, it may be interesting to measure the energy produced as the energy cost and related CO_2 emissions are significant due to the fuel/oil consumption. A simple energy meter is generally sufficient to measure the energy production. However data such as voltage and current can be useful for alarming and then lead to select a 210 metering index.

Sub-distribution board feeders

- **Rating current < 630 Amps**

Active and reactive power to identify easier reactive power consumer
Phase current to detect unbalanced phases.

- **Rating current > 630 Amps**

In addition to the previous requirements, it is advisable for this rating:
- To limit the uncertainty of the measurement by selecting a meter with 0,5 class accuracy
- To collect the harmonic distortion (THD): this will ease the analysis to identify harmonics sources
- To measure neutral current to detect overloads in neutral conductor (third-order harmonics due to non-linear single phase)
- To follow energy consumption and maintenance parameters with overload alarming and min/max of Power/ Voltage/ Current. This is especially important when the “process” may evolve with time such as implementation of new equipment in a production line for an industrial building.

Applications such as sub-billing for a tenant area requires an accuracy of 1% and data logging in case of power outage or problem with the communication devices to avoid the loss of data. For cost allocation, 2% accuracy is sufficient.

Special feeders in the main switchboard

“Special” refer to feeders that supply:

- Critical loads that don’t accept interruptions or only short interruptions such as cash register in a supermarket
- Loads such as motor with variable speed drive or lighting (high power feeder in an hypermarket) that may disturb sensitive loads.

For these feeders, energy consumption measurement shall be combined with installation and power quality monitoring in terms of measurement of electrical parameters with harmonic analyses and data that reduce curative maintenance and that enable preventive and predictive maintenance.

- **Rating current < 63 Amps**

- Main electrical parameters to check the proper performance and power supplies of the load
- Communication output to be informed in case of malfunctions.

- **Rating current < 630 Amps**

In addition to the previous requirements, it is advisable for this rating to collect:
- Harmonic distortion (THD) for loads that produces harmonics (motor, lighting, IT server) – especially for motors, harmonic distortion may also reveal some problems as the current is directly an image of the motor health and can help to decide to do preventive maintenance on this motot..
- Overload alarming and min/max of Powers/ Voltage/ Current to follow energy consumption and maintenance parameters for sensitive loads.
- In case of high harmonic producer, neutral current has to be measured to detect overloads in the neutral conductor.

- **Rating current > 630 Amps**

In addition to the previous requirements, it is advisable for this rating:
- To limit the uncertainty of the measurement by selecting a meter with 0,5 class accuracy and enable to check the energy bill
- To be able to perform event analysis for the maintenance team, it leads to select meter with event stamping
- To get the load profile to identify source of peak demand for contract optimization.

Special feeders in a sub-distribution board

- **Rating current < 63 Amps**

- Energy consumption
- Main electrical parameters to check the proper performance and power supplies of the load.

- **Rating current < 630 Amps**

- Communication output to be informed in case of malfunctions.

Common feeders

> Rating current < 63 Amps

A simple energy meter is sufficient to measure the energy consumption.

> Rating current < 630 Amps

In addition to the previous requirements, it is advisable for this rating to collect:
- Main electrical parameters (voltage, current) to check the proper performance and power supplies of the load.

> Rating current > 630 Amps

In addition to the previous requirements, it is advisable for this rating to collect:
- Communication output to be informed in case of malfunctions.

4.5.2 Non electrical meters

For non electrical meters, we recommend to refer to the corresponding manufacturer or to the following documents that gives an overview of flow meters technologies and advices for selection:
- Selecting the Right Flowmeter— By Corte Swearingen
- Chapter 5 of Metering best practices – A guide to achieving utility resource efficiency – US Department Of Energy – October 2007.

5 Case study

The case study is a mid-range hotel of 5 000m^2 with 200 bedrooms that belong to a hotel chain.

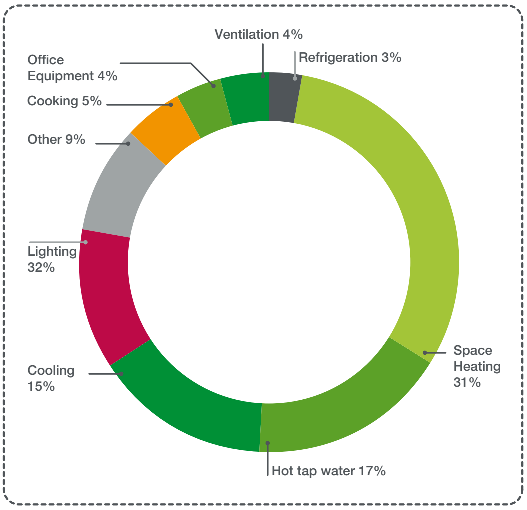
5.1 Objectives

The main objectives of the corporate energy manager are to be able to perform building benchmarking and to be able to understand how each hotel operates to propose to the hotel director the relevant energy conservation measures.

5.2 Performance metrics

To be able to compare energy consumptions, the first step is to group together hotels of the same category.

For this case study, we will focus on mid-range hotels of this hotel chain. In such hotel, the main energy users are Heating, Cooling, Domestic hot water, Catering and lighting and the main factors that will impact the consumptions are the number of bedrooms, the climate and the occupancy level (or number of overnight stays). Therefore these factors shall be used to normalize the data in order to be able to perform consistent comparisons between hotels.



The following performance metrics can be defined to meet the above objectives:

1. Whole building Energy Use Intensity (EUI) kWh/m^2 and kWh/occupancy level
2. Whole building electricity EUI kWh/m^2 and kWh/occupancy level
3. Whole building gas EUI m^3/m^2/HDD and CDD (Heating Degree Days and Cooling Degree Days) as it is mainly used for heating and domestic hot water
4. Whole building water Use intensity m^3/ occupancy level
5. Whole building electrical consumptions breakdown per Time Of Use (TOU)
6. Whole building electrical power demand kWh with identification of over demand periods
7. Whole building Reactive energy consumption kvarh
8. Whole building space heating EUI kWh/m^2/HDD and CDD
9. Whole building Domestic How Water EUI (production) kWh/m^2 and kWh/occupancy level
10. Whole building Domestic How Water volume intensity m^3/m^2 and m^3/occupancy level
11. Total cooling consumption EUI kWh/m^2/HDD and CDD
12. Total ventilation EUI kWh/m^2
13. Kitchen electrical consumption kWh
14. Kitchen cold water consumption m^3/m^2
15. Lighting consumption for common areas kWh/m^2

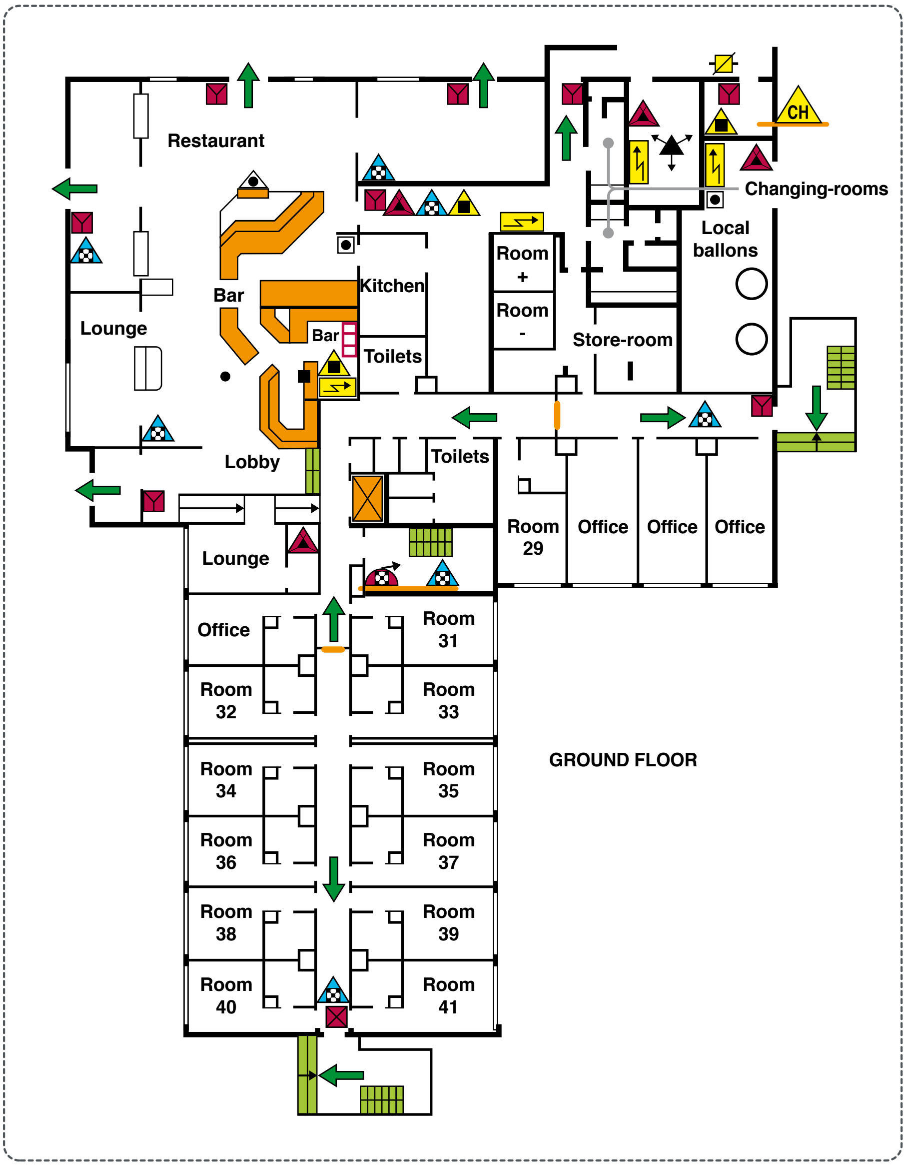
5.3 Points of measurement

We need now to identify the necessary data to build the performance metrics.

		Necessary data to build the performance metrics	
	Performance metrics	Static data	Dynamic data
1	Whole building EUI (kWh/m^2 and kWh/occupancy level)	Gross floor area (m^2) kWh/m^3 ratio for gas	Building electrical consumption (kWh) Building gas consumption (m^3) Occupancy level
2	Whole building electricity EUI kWh/m^2 and kWh/occupancy level	Gross floor area (m^2)	Building electrical consumption (kWh) Occupancy level
3	Whole building gas EUI m^3/m^2/HDD	Gross floor area (m^2)	Building gas consumption (m^3) Outdoor temperature (for HDD)
4	Whole building water use intensity m^3/ occupancy level		Water consumption (m^3) Occupancy level
5	Whole building electrical consumptions breakdown per TOU		Building electrical consumption (kWh) TOU signals
6	Whole building electrical power demand	Gross floor area (m^2)	Main electric power (kW)
7	Whole building space heating EUI kWh/m^2/HDD	Gross floor area (m^2)	Gas consumption for space heating boiler Outdoor temperature (for HDD)
8	Whole building DHW EUI kWh/m^2 and kWh/occupancy level	Gross floor area (m^2) kWh/m^3 ratio for gas	Gas consumption for DHW boiler Water pumps consumptions (kWh)
9	Whole building DHW volume intensity m^3/m^2 and m^3/ occupancy level	Gross floor area (m^2)	Cold water volume entering the DHW system (m^3) Occupancy level
10	Total cooling EUI kWh/m^2/HDD	Gross floor area (m^2)	Chiller consumption (kWh).Water pumps consumptions (kWh) Outddor temperature (for HDD)
11	Total ventilation EUI kWh/m^2	Gross floor area (m^2)	Kitchen electrical consumption
12	Kitchen electrical consumption (kWh)		Kitchen electrical consumption
13	Kitchen water consumption (m^3)		Kitchen water consumption (m^3)
14	Lighting common areas EUI	Gross floor area (m^2)	Lighting consumption of common areas (kWh)

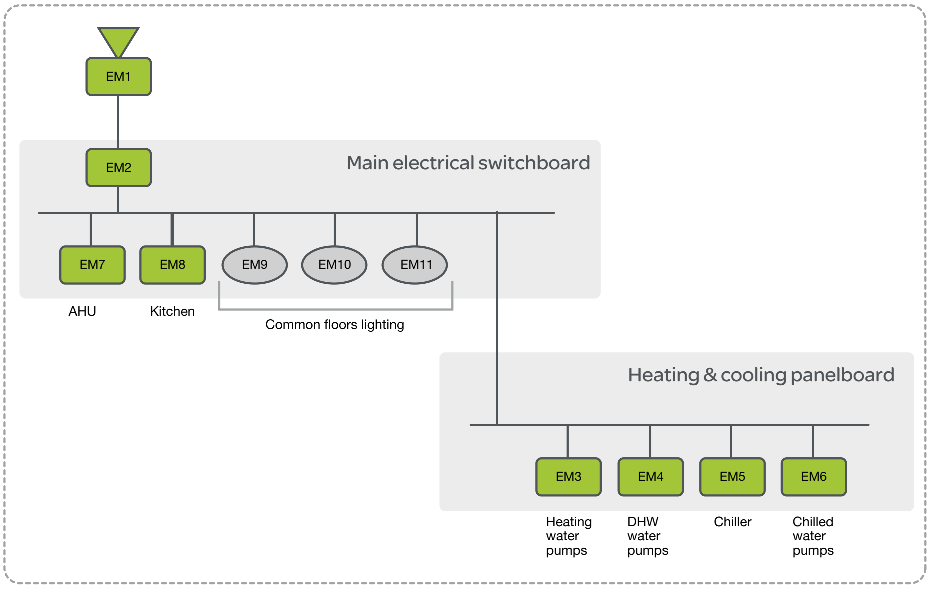
At this stage, we need to consider the building topology with locations of main incoming meters, electrical and mechanical rooms and network distributions to be able to define all necessary point of measurements. Most of the performance metrics can be built thanks to direct metering method. However, other methods are selected for 2 metrics:

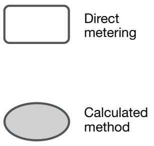
- Metering common lighting consumption with a direct metering method will be too costly because it would lead to add 4 meters in each floor panelboard to be able to separate lighting from other end-use consumptions. Therefore, we decide to measure each panelboard consumption and to identify during the night the common lighting consumption.
- Gas consumption for DHW boiler: as there is no gas for cooking, we can use the difference between the whole gas building consumption and the gas consumption for space heating boiler to calculate this metric.



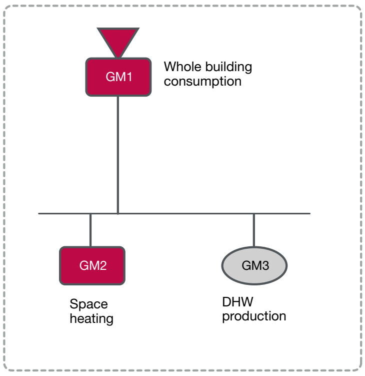
Metering diagrams with the different points of measurement

Electrical diagram

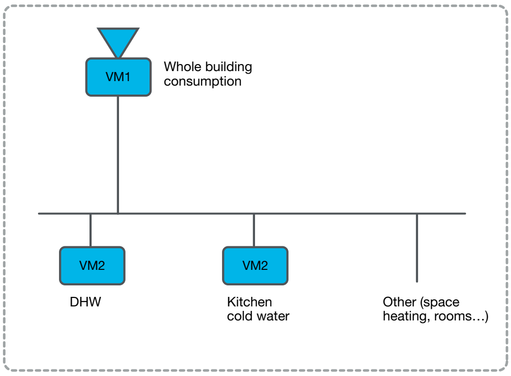




Gas diagram



Water diagram



5.4 Using existing meters

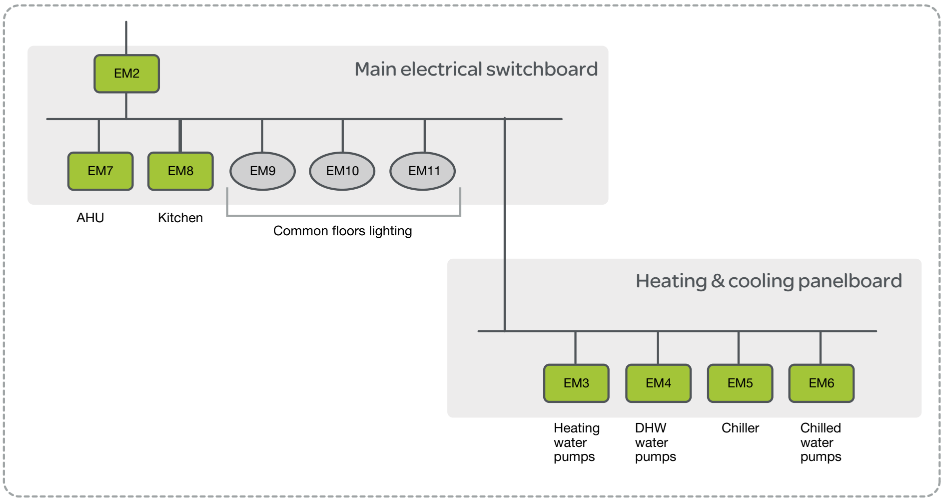
The following meters exist already and can be re-use to collect the necessary data:

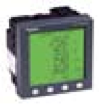
- Main electrical meter to collect TOU signals (EM1)
- Main water meter (WM1)
- Main gas meter (GM1)
- Space heating boiler gas meter (GM2).

5.5 Selecting additional meters

Finally, the last step is to select the right features for new meters.

Electrical meters



Selected meter		EM	Rating	Meter characteristics
	PM750 with split core (only 2 hours shutdown was acceptable)	EM2	< 630 amps	
	NSX circuit-breaker with Micologic 5.2E trip-unit	EM5, EM7, EM8, EM9, EM10, EM11	< 250 amps	
	PM9p with solid core	EM3, EM4, EM6	< 63 amps	

	Necessary data to build the performance metrics		
Performance metrics	**Static data**	**Dynamic data**	**Recording frequency**
Whole building EUI (kWh/m^2 and kWh/occupancy level)	Gross floor area (m^2) kWh/m^3 ratio for gas	Building electrical consumption (kWh)	yearly, monthly
		Building gas consumption (m^3)	yearly, monthly
		Occupancy level	yearly, monthly
Whole building electricity EUI kWh/m^2 and kWh/occupancy level	Gross floor area (m^2)	Building electrical consumption (kWh)	yearly, monthly, weekly, daily
		Occupancy level	yearly, monthly
Whole building gas EUI m^3/m^2/HDD	Gross floor area (m^2)	Building gas consumption (m^3)	yearly, monthly, weekly, daily
		Outdoor temperature (for HDD)	daily
Whole building water use intensity m^3/ occupancy level		Water consumption (m^3)	yearly, monthly, weekly, daily
		Occupancy level	yearly, monthly
Whole building electrical consumptions breakdown per TOU		Building electrical consumption (kWh)	yearly, monthly
		TOU signals	N/A
Whole building electrical power demand	Gross floor area (m^2)	Main electric power (kW)	yearly, monthly
Whole building reactive energy consumption (kvarh)		Electrical reactive energy (kvarh)	yearly, monthly
Whole building space heating EUI kWh/m^2/HDD	Gross floor area (m^2)	Gas consumption for space heating boiler	yearly, monthly
		Water pumps consumption (kWh)	
		Outdoor temperature (for HDD)	
Whole building DHW EUI kWh/m^2 and kWh/occupancy level	Gross floor area (m^2) kWh/m^3 ratio for gas	Gas consumption for DHW boiler	yearly, monthly
		DHW pumps consumptions (kWh)	
Whole building DHW volume intensity m^3/m^2 and m^3/occupancy level	Gross floor area (m^2)	Cold water volume entering the DHW system (m^3)	yearly, monthly
		Occupancy level	yearly, monthly
Total cooling EUI kWh/m^2/HDD	Gross floor area (m^2)	Chiller consumption (kWh)	yearly, monthly
		Water pumps consumptions (kWh)	yearly, monthly
		Outddor temperature (for HDD)	yearly, monthly
Total ventilation EUI kWh/m^2	Gross floor area (m^2)	AHU electrical consumption	yearly, monthly, daily
Kitchen electrical consumption (kWh)		Kitchen electrical consumption	yearly, monthly, daily
Kitchen water consumption (m^3)		Kitchen water consumption (m^3)	yearly, monthly, daily
Lighting common areas EUI	Gross floor area (m^2)	Lighting consumption of common areas(kWh)	yearly, monthly, daily

Points of measurement		
Measurement method	**Meter**	**Location**
Direct metering	Electrical meter - main switchboard incoming (EM2)	Main electrical room
Direct metering	Main gas meter (GM1)	Outside building
N/A	Manual reading from Hotel management system	
Direct metering	Electrical meter - main switchboard incoming (EM2)	Main electrical room
N/A	Manual reading from Hotel management system	
Direct metering	Main gas meter (GM1)	Outside building
Direct metering	Temperature sensor PT100 (TM1)	Outside building
Direct metering	Main Water meter (WM1)	Building entrance
N/A	Manual reading from Hotel management system	
N/A	Electrical meter - main switchboard incoming (EM2)	Main electrical room
Direct metering	Main electricity meter (EM1)	Main electrical room
Direct metering	Electrical meter - main switchboard incoming (EM2)	Main electrical room
Direct metering	Electrical meter - main switchboard incoming (EM2)	Main electrical room
Direct metering	Gas sub-meter (GM2)	Boiler room
Direct metering	Electrical meter (EM3)- heating water pumps feeder	Boiler room
Direct metering	Temperature sensor PT100 (TM1)	Outside building
By difference GM1-GM2	N/A	N/A
Direct metering	Electrical meter (EM4) - DHW pumps feeder	Boiler room
Direct metering	Flow meter (WM2) at entrance of the hot water tank	Boiler room
N/A	Manual reading from Hotel management system	
Direct metering	Electrical meter (EM5) - Chiller feeder	Boiler room
Direct metering	Electrical meter (EM6) - Chilled water pumps feeder	Boiler room
Direct metering	Temperature sensor PT100 (TM1)	Outside building
Direct metering	Electrical meter (EM7) - AHU feeder	Main electrical room
Direct metering	Manual reading from Hotel management system	
Direct metering	Water sub-meter (WM3)	?
By data analysis - from general service consumption	Electrical meter (EM8) - General services panelboard feeder	Main electrical room

Author: Jean-Paul Genet, Offer Manager
Design: pemaco