Designing a metering system for small and medium-sized buildings

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Schneider Electric

Contents

1 Introduction

Energy efficiency systems can increase property values, facilitate resale, and boost rental occupancy rates and yields. Many such systems are also cost-effective to set up and guarantee rapid return on investment. One thing that all energy-efficiency measures have in common is the need for reliable, accurate metering and monitoring of energy consumption. When it comes to commercial buildings, installing an effective WAGES (water, air, gas, electricity, steam) metering system can be a source of substantial energy and cost savings.

This white paper examines WAGES metering as the essential first step toward achieving greater energy efficiency in small to medium-sized non-critical commercial buildings. Critical buildings like hospitals and data centres present specific power-quality requirements that fall outside the scope of this white paper. This white paper covers metering technology, metrics, and metering points.

2 Reference documents

[1] Guidance for Electric metering in Federal Buildings, 2006, US Department of Energy

[2] Metering Best Practices, 2007, US Department of Energy

[3] Measured Success: Constructing Performance Metrics for Energy Management, John Van Gorp

[4] Procedure for Measuring and Reporting Commercial Building Energy Performance, National Renewable Energy Laboratory

[5] Livre Blanc: Pilotage de la performance énergétique, GIE Bouygues

[6] GIL 65 Metering Energy Use in New Non-domestic Buildings, CIBSE

[7] La mesure dans un projet d’efficacité énergétique, 2008, Gimelec

[8] Energy Efficiency in Buildings, Guide F, CIBSE

[9] Guidelines for the Evaluation of Building Performance: Building EQ, Christian Neumann and Chris Jacob

3 Achieve energy savings of up to 30%

The case for energy efficiency is clear. By 2030 electrical consumption will be over 70% higher than it is today[1] and energy efficiency solutions will account for 57% of reductions in GHG (greenhouse gas) emissions[2]. The American Council for an Energy Efficient Economy identifies energy efficiency – along with renewable energies – as one of the pillars of sustainable energy policy.

Energy efficiency can be defined as the ratio between energy consumed and energy produced. In other words, it is the ability to perform the same function with less energy – the goal of any energy management system. In a 2006 report, the International Energy Agency stated that improving the energy efficiency of buildings, industry, and transport could reduce world demand for energy by one-third by 2050 and help lower GHG emissions substantially. The energy used for buildings – and space heating[3] in particular – is the single largest producer of GHGs, while electricity accounts for up to 50% of CO_2 emissions attributable to residential and commercial buildings.

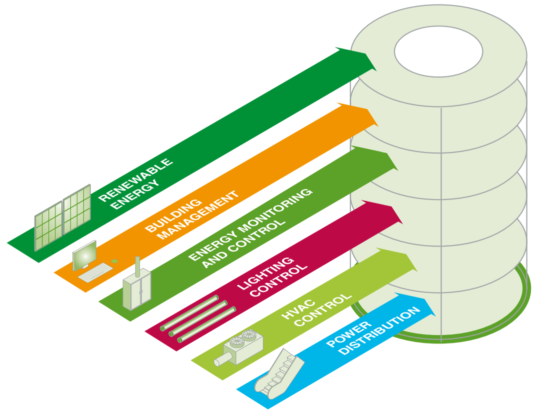
In the EU so much energy is lost through roofs and walls alone that Europe could meet its entire Kyoto commitment just by improving insulation standards. Similarly, APEC energy ministers state in point nine of the Fukui Declaration: “Energy-efficient buildings and appliances are key to a sustainable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

Active and passive energy efficiency

There are two approaches to managing energy more efficiently: passive energy efficiency and active energy efficiency. Passive homes, for instance, use insulation, heat recovery, and solar heating to achieve energy self-sufficiency. However, the passive approach alone is not enough. Energy efficiency is by nature a long-term endeavour that requires active demand management. The ultimate goal is for buildings to produce more energy then they consume, a trend that is reflected in recent regulations. The EU Energy Performance of Buildings Directive (EPBD), for instance, requires all new buildings to be nearly zero-energy by 2020.

And yet, most buildings will not be positive-energy by 2020. The positive-energy buildings that do exist will be outnumbered by older properties built before the EPBD, which, in any case, only applies to Europe. Whether buildings are older and less energy-efficient or state-of-the-art positive energy buildings, metering and monitoring are the basic building blocks for efficient energy management.

Effective metering and monitoring give owners and operators crucial information about how their buildings are performing so that substantial, almost-immediate improvements can be implemented. For example, an effective metering and monitoring system has the capacity to get tenants, property managers, and owners involved in energy-efficiency measures. The ability to identify and quantify energy usage is often sufficient to bring about energy-saving changes in practices and behaviours, such as reducing waste and avoiding peak utility rates. In a single-operator, owner-occupied office building, for example, the introduction of effective metering and monitoring systems brings immediate energy savings of 10% and can also help reduce building operating costs.



Solutions for all building applications

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 declaration on low carbon paths to energy security: cooperative energy solutions for a sustainable APEC.

Automatic metering: the cornerstone of energy efficiency

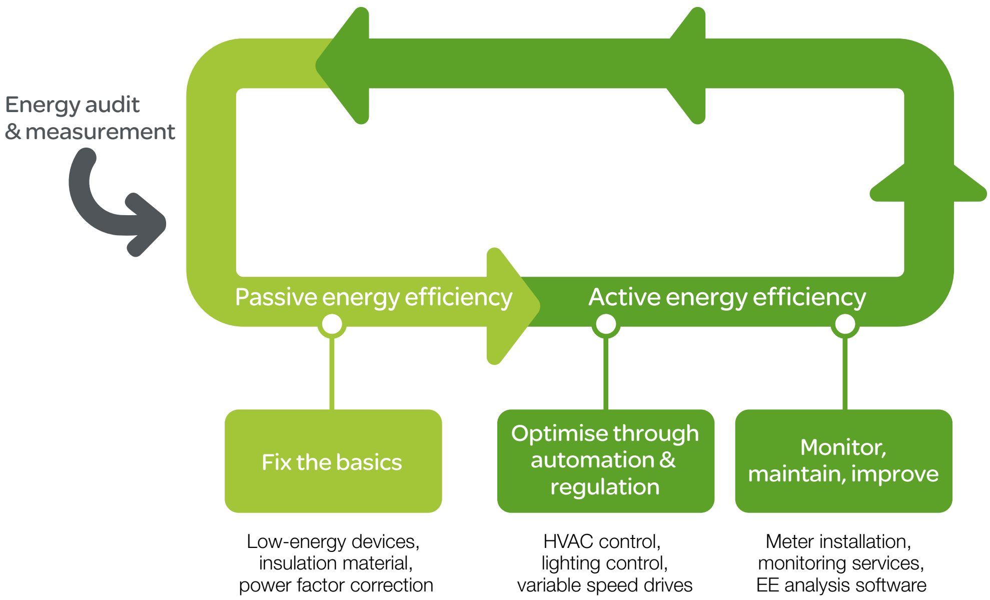
Continuous automatic metering systems often use dynamic energy dashboards to display information about building operation and energy consumption. Features like graphs, tables, and widgets are used to illustrate data in a meaningful way, such as homing in on and tracking specific loads. For example, an energy dashboard may show that a building's ventilation system is over consuming. One easy solution would be to reduce motor speed by only a few Hz to curb consumption with no negative impact on performance. Going a step further, automation and control systems offer a more effective, longer-term contribution to overall building energy efficiency. When combined with effective automatic metering, these systems, which include variable speed motors for ventilation, indoor and outdoor lighting control, smart thermostats, and time-programmable HVAC systems, ensure that a building uses only the energy it needs.

Whether a building is equipped with simple energy dashboards or is outfitted with a full-fledged automation and control system, continuous automatic metering also gives building owners, operators, and occupants access to the data they need to optimise their current electricity supply contracts or negotiate new ones. Multisite facility managers and building operators can also aggregate loads to negotiate bulk utility contracts. Accurate shadow bills can be used to spot utility billing errors and determine whether suppliers are complying with contract terms.

The cornerstone of effective energy management, continuous automatic metering provides real-time information, alarms, and simple load control and, in some cases, recommendations for corrective actions. And, when measured against user-defined metrics, continuous automatic metering can deliver historic and predictive energy intelligence for high-precision energy efficiency.

Continuous automatic metering can help building owners, operators, and occupants:

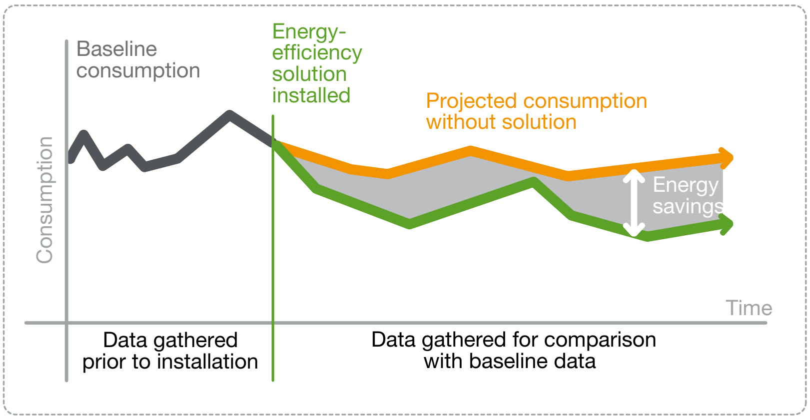
- Identify cost-cutting opportunities by spotting inefficiencies, trends, and changes
- Manage demand to reduce exposure to price volatility and system reliability risks
- Improve energy usage by comparing energy costs across facilities
- Benchmark facilities internally and externally
- Allocate costs 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 (like kWh/m² and kWh/occupant for electricity consumption in an office, for instance). If a building is seeking LEED green building, BREEAM, or similar certifications, metering can be used to measure and track electricity use for each required space and function. Similarly, users can know and show their energy cost management (ECM) performance against a measurement and verification metric like the IPMVP, thereby avoiding penalties and demonstrating progress toward carbon commitments.

Achieve measurable savings

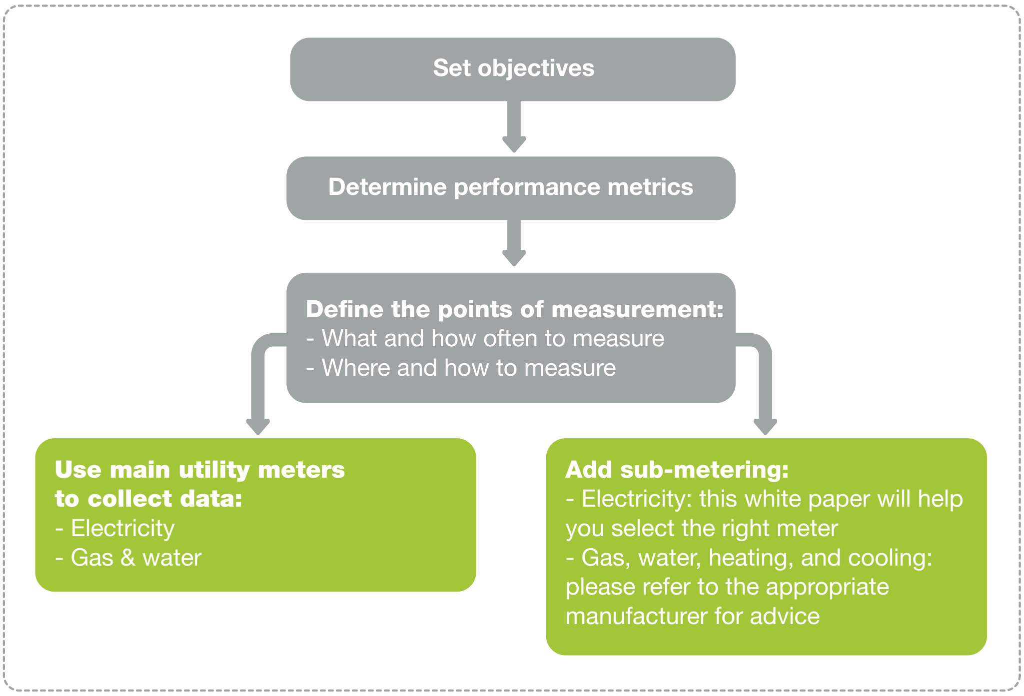


We use the International Performance Measurement and Verification Protocol (IPMVP) to measure and verify the energy savings we promise for our energy-efficiency solutions:

- 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 measurement. Energy efficiency is cost effective and earns rapid ROI. It increases property values, makes more attractive market prospects, and increases rental occupancy rates and yield.

4 Method



4.1 Set objectives

The first step to greater energy efficiency through metering and monitoring is to set objectives for the future system. Ideally, users of the system are involved in this process, and are given an opportunity to provide input on the main features to be included in the system. This step is essential to identifying user needs and determining the scope of the future energy monitoring system.

The main applications of an energy monitoring system are:

- 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 certification compliance

These high-level objectives must be customised to meet the unique needs of each energy monitoring project.

4.1.1 Energy cost allocation

For buildings where cost allocation is used, energy costs are commonly allocated using a formula based on the floor area occupied by each tenant relative to the total floor area of the building. However, many tenants are beginning to consider this type of cost allocation inaccurate and unfair and are asking to be billed only for their actual usage.

For buildings with some form of metering in place, meters are typically read manually, 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. And yet reliable, accurate cost allocation is a competitive requirement and, in some cases, the de facto standard.

Cost allocation

By measuring the energy consumed at different points on the network, users gain an opportunity to take ownership of their energy costs at the appropriate level in an organisation. This helps drive behavioural changes and lower costs.

4.1.2 Energy sub-billing

For buildings that have no sub-metering system in place at all, energy and demand costs are often not passed on to tenants. Property owners that want to recover the costs of supplying electricity to individual tenants may encounter a number of obstacles to implementing tenant sub-billing. For example, some countries prohibit billing based on sub-metering each tenant space. Where local laws do allow billing based on the use of sub-metering, more accurate billing is possible; however, the cost of implementing this type of sub-metering system has traditionally been prohibitive.

Sub-billing

Accurate measurement at the energy delivery point enables multi-tenant building operators to assess each tenant's exact consumption. This encourages accountability and more energy-efficient habits among tenants while generating revenue for building owners.

4.1.3 Energy usage analysis

For businesses, energy is a major operating cost. To extract maximum financial and competitive advantage 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 understand the characteristics of their energy consumption, identify the opportunities with the biggest ROI, keep energy-efficiency projects on track, and verify results.

4.1.4 Building energy performance benchmarking

Benchmarking allows users to compare the efficiency of one building or application (HVAC, lighting, IT) in an office building against others, or against real estate market statistics. Benchmarking can reveal inefficiencies and isolate key contributing factors, helping to identify the right places to target improvement projects that won't have a negative impact on business or users. Such improvements include equipment upgrades, process changes, and optimising building performance according to weather conditions, occupancy, or other factors.

4.1.5 Electrical distribution asset management

Constant monitoring of the installation gives facility and property managers the information they need to improve usage and behaviour, lower electrical consumption, reduce capital expenditures, and cut energy costs.
An electrical distribution asset management system accurately meters energy consumption and demand throughout each facility and automatically generates load profiles that provide insight into historical and present load patterns.

The data gathered can reveal hidden, unused capacity for each building, floor, feeder, area, or piece of equipment. This spare capacity can then be better leveraged without the need for additional capital expenditures on upgrades. It can also reassure building operators that the existing infrastructure will be able to handle fluctuations in building occupancy – and thus demand – again, minimising capital expenditures. “Right sizing” the power distribution system to meet, but not exceed, the requirements of new facilities, expansions, or retrofits, is a key opportunity for savings.

4.1.6 Bill auditing (shadow metering)

WAGES billing errors are surprisingly common. Because most supply contracts allow the utility to recover missed charges only months or years after an error has occurred, under-billing can be as problematic as errors in the utility’s favour. For a commercial building, this lengthy error identification and recovery process potentially means that costs will not be recouped from tenants if a new tenant moves into the space before the issue is resolved.

Under- or over-billing can result from meter reading and data entry errors. 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 all utility bills received to identify any errors and/or anomalies and to have the information necessary to support any cost recovery claims. A secondary meter, typically called a shadow meter, can be connected in parallel to the utility meter. Software then reads the energy data picked up by the shadow meter and calculates an accurate shadow bill that can include all expected energy and demand charges.
This bill can then be compared to the utility’s bill to identify any inconsistencies. Bills can be verified either manually or by inputting the actual utility bill data into the software for comparison.

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 aggregated 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 optimise costs without sacrificing reliability and quality of supply.

4.1.8 Demand/response

This feature offers the consumer the ability to take advantage of discounted electricity rates by reducing consumption on demand (on a case-by-case or commitment basis). A demand/response system will first help the user to assess whether participation in a specific event is economically advantageous. If it is, the system will help quickly determine where and how much load can be reduced in response to the curtailment request. Finally, demand/response systems can help consumers efficiently coordinate a load curtailment strategy by automatically shedding loads or starting up generators during the event period.

4.1.9 Regulatory or certification compliance

There are several local regulations that require energy metering for buildings that exceed a certain floor area such as Building Regulations Part L2 in the UK:

> *"Reasonable provision of meters would be to install incoming meters in every building greater than 500m² 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 obtain a certification like LEED, BREEAM, or HEQ. Each of these certifications includes a section about WAGES monitoring and strongly encourages the use of sub-metering either by area or energy use.

4.2 Determine performance metrics

Before deciding which data to gather, it is important to determine which data will be needed to meet the objectives of the future metering and monitoring system. These performance metrics are the translation of project objectives into measurable data ([3]), and usually show up on the future system's energy dashboards. Performance metrics link building activity and consumption. Below are some examples of performance metrics.

4.2.1 Performance metrics for EPBD compliance

If one of the project goals is to be compliant with EPBD, two performance metrics which make up the EPC are mandatory for the whole building:
• Energy Efficiency Rating (KWh ep/m²/year)
• Environmental impact (CO_2) Rating(kg eqCO_2/m²/year)

4.2.2 Performance metrics for whole-building benchmarking

For building benchmarking, the main metrics are:
• Main supplies
• Renewable energy production
• Specific energy uses that are normally not typical of that activity sector (called separable energy use) or that are very different for each building, such as laboratories on a university campus or leisure facilities in an office building; including these energy uses may reduce the validity of the benchmark and should be deducted from the total energy consumption to compare values of different buildings.

To allow building benchmarking, it is also very important to normalise consumption. The data used may differ according to the activity sector; for example, the performance metric for total consumption is expressed in:
• kWh/m² and kWh/occupant for an office
• kWh/occupancy rate or kWh/overnight stay for hotel
• kWh/production rate for an industrial building.

The data should also be corrected with heating degree days and cooling degree days to compare current building consumption with previous years and with buildings in other locations.

4.2.3 Performance metrics for energy usage analysis

Of course, performance metrics can be used to gain an understanding of overall performance, such as total utility consumption (gas, electricity, heating oil). However, they can also be expanded for a more detailed analysis of building energy and water consumption. If an energy manager wants to get a clear picture of how energy is used in the building or track deviations from a target, per-area and per-energy-use analysis capabilities are strongly recommended.

The first step is to break the building down into sub areas with similar activities and comparable major consumption patterns:
- Outdoor
- Parking
- Catering
- Common area
- Tenant area

The second step is to identify the different energy uses. A typical energy use breakdown for a commercial building might include:
- Lighting
- Heating
- Cooling
- Ventilation
- Domestic hot water
- Other (office equipment)

These breakdowns can then be used to select which energy uses in which areas need to be monitored. This is the basis for developing an appropriate metering strategy and determining the associated performance metrics.

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

To complete your building and energy use breakdown, major sources of consumption will first need to be identified using the following tools:
- Energy audit
- Building benchmarking
- Simulation

4.2.4 Performance metrics for bill auditing

To effectively audit energy bills and reduce spending, knowing a building's overall consumption is not enough, especially for electricity. The most important factor is to be able to reproduce the tariff structure, which may depend on the end-user contract.

For electricity, the main performance metrics are:
• 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 data must be picked up at the same frequency as the main utility meter. Generally, a pulse from the main meter indicates this frequency (every 10 or 15 minutes).

4.2.5 Performance metrics for LEED

LEED certification includes several metering requirements, which vary depending on the type of project. Therefore, the related performance metrics also vary.

> 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 estimated energy use. Performance metrics are determined 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 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, and process water use (2 points).

> Credit EBOM2009 EAc3 – Performance Measurement
System-level Metering – 1 or 2 points
This credit encourages the use of building system sub-metering to enhance the operational staff's ability to analyse specific energy loads and pinpoint potential areas for improvement in system-level or equipment performance. It requires:
• A breakdown of the largest energy use categories covering 40% or 80% of total consumption (according to ASHRAE energy audit)
• A minimum number of the previous categories covering at least 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 sub-metering of energy produced by the renewable energy system 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 sub-metering equipment to measure and record energy use within the tenant space.

• Case 2: project covering 75% or more of the total building area (5 points)

Continuous metering equipment must 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 metering requirements below are mandatory for BREEAM certification:

Issue Ene 2 – Sub-metering of Substantial Energy Uses – 1 point

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 point

Provision of accessible sub-meters covering the energy supply to all tenants, or in the case of single occupancy buildings, relevant function areas or departments within the building/unit.

Issue Wat 2 – Water Meter – 1 point

Water consumption shall be monitored as follows:

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 monitoring of water consumption. There is special innovation credit for sub-metering of individual areas where demand in such areas is equal to or greater than 10% of the total water demand of the building.

4.3 Determine the metering points

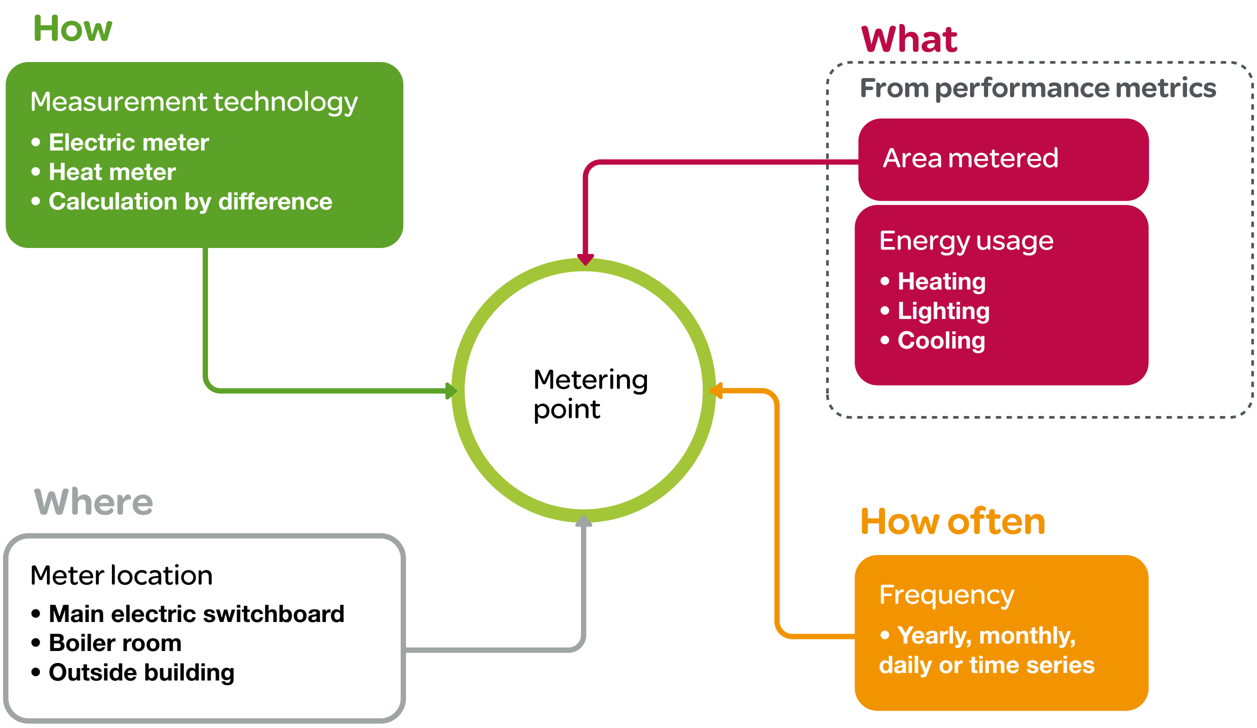
The metering system must be designed to ensure that the data gathered will enable the desired analysis. The data must also allow operators to monitor and control the building according to their objectives.

An effective metering system design must avoid the following pitfalls:

- Gathering insufficient data to enable building consumption analysis
- Gathering and analysing too much data that are never used, tying up resources that could have been used for other energy efficiency actions.

The metering point is the combination of the type of meter and its location. To determine the most effective metering points throughout the building, it is helpful to look at the following questions:

- What data is required to calculate the performance metrics? How often must the data be gathered?
- How and where must this data be gathered?



4.3.1 What data must be gathered?

For each performance metric, the required data can be split into two categories:

• Static data such as building area, rating, or efficiency of equipment. These data are usually used to normalise measurements for benchmark comparisons.

• Dynamic data such as energy consumption, temperatures, or 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 below gives examples of these two categories for a commercial building:

Data required to build performance metrics

Performance metrics	Static data	Building	Recording frequency
Building energy use intensity (kWh/m²)	Gross floor area (m²)	Building energy use (kWh)	Monthly
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 consumption (kWh) Building gas consumption (m³)	Monthly, daily
Building gas consumption (m³)		Building electrical consumption (kWh) Building gas consumption (m³)	Monthly, daily
Building electrical consumption (kWh)		Electrical consumption from utility Photovoltaic production (kWh)	Monthly, daily
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	Monthly, daily Monthly, daily
DHW energy use (kWh)	Conversion factor from m³ to kWh	Boiler gas consumption (m³)	Monthly, daily
DHW load (kWh)		Boiler production (kWh)	Monthly, daily
…	…	…	…

The recording frequency depends on the project objectives:

• For energy usage analysis or energy consumption alarming, measurement every 10 to 15 minutes is necessary to generate load curves.

• For energy sub-billing or bill auditing, the recording frequency must be compatible with the tariff structure (once a day could be enough for a 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 Measurement method and meter location

Once the measurement method and meter locations have been determined, the data above can be used to identify the metering points throughout the building. When dealing with existing buildings in particular, practicality is a major concern and should be checked according to the electrical architecture and wiring; whether or not it is feasible to separate lighting and small power consumption; gas distribution; and accessibility of water meter, for example.

4.3.2.1 Measurement method

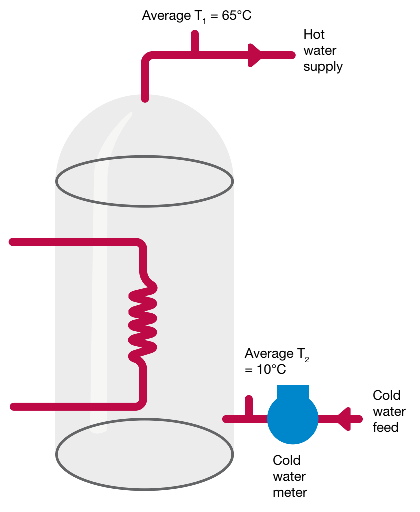
CIBSE guide GIL 65 “Metering energy use in new non-domestic buildings” [6] describes different methods for measuring energy consumption. We added several of our own suggestions to this list and assessed the situations in which each method is most appropriate.
Measurement methods should be chosen according to project goals like the desired level of accuracy, estimated budget, and operating conditions. This analysis should result in a list of the meters to install throughout the building.

• **Direct metering:** Measures consumption directly via electric power meters, gas meters, oil meters, heat meters, and steam meters. Direct metering is appropriate the followings cases:
- For major loads or overall building consumption.
- When measurement is used tenant sub-billing, as it requires class 1 or 0.5 accuracy.
- When measurement of other data like electric power quality is required for the same energy use. Therefore, disruptive or interruption-sensitive loads should be identified at a very early stage when designing the metering system.

• **Hours counter:** For constant-power loads like fans without VVDs or lighting, measuring the number of operating hours is one way to calculate consumption. Knowing the rating power indicated on the equipment plate is not always sufficient, however, as the load factor has to be taken into account to estimate consumption accurately. For existing buildings, the load factor can be measured using a portable meter. If there is load control (e.g., lighting control with occupancy sensors), it becomes very difficult to estimate the load factor, and this method is no longer appropriate.

Electromechanical meter

• **Indirect metering:** Readings from indirect meters can be used to measure energy consumption as illustrated below:

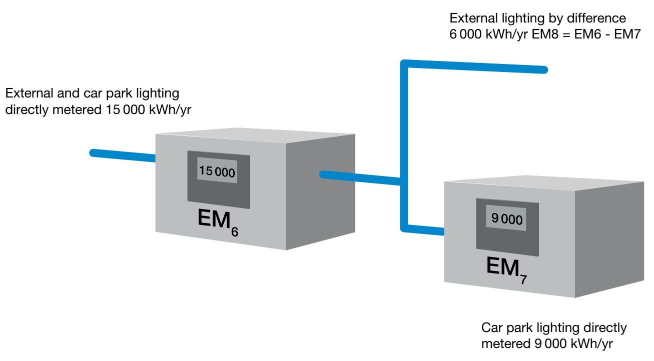


$$\text{Estimated consumption} = \frac{\text{metered feed water (litres/yr) x Temp Diff (T1 - T2) x 4.185}}{\text{boiler efficiency 75\% x 3600}}$$

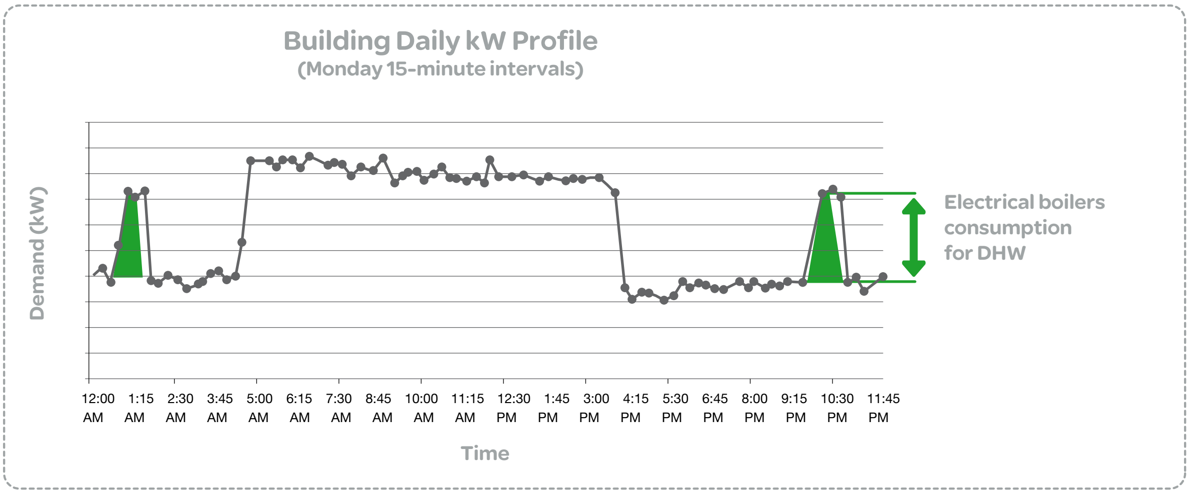
$$= \frac{844,574 \times (65 - 10) \times 4.185}{0.75 \times 3600} = 72{,}000 \text{ kWh/yr}$$

Generally, the accuracy of an estimation depends on the equipment data (such as the boiler efficiency rating shown above), which can change or evolve with time. Therefore, these data must be checked regularly.

• **Calculation by difference:** Two direct meters can be used to determine a third measurement by difference. This method should only be used if the two other measurements are acquired through direct metering. This method should not be used if a very small source of energy consumption is subtracted from a very large one, as the margin of error could be higher than the smaller consumption value.



• **Calculation by data analysis:** Based on information about how the building operates, one measurement can be used to break down different energy usages or to determine the consumption for different areas. It a hotel, for example, if you know that at night most of the electrical consumption on the floors is from common areas (corridor lighting), the floor electrical consumption during this time slot is equal to the consumption of the common area. Therefore, metering the floor panel board feeder is sufficient; installing additional meters is not necessary. The chart below shows how night-time electric boiler consumption is determined by metering only the overall building load.



• **Estimation:** The consumption of small power loads can be estimated using a ratio (e.g. kWh/m²). Ratios are either provided in some standards or are based on known occupant behaviour. For example, plug-in lighting consumption can be estimated through the number, power rating, and use patterns of lamps.

4.3.2.2 Meter location

Meter locations are determined according to which energy flow they need to measure (based on the schematic diagram). However, other criteria should also be taken into account:

• Practicality

• Visibility: meters must be placed so that they can be read easily by the building operator; typically, in the plant room, main distribution room, or control room

• The possibility of reusing existing meters.

Special consideration for electric meter location

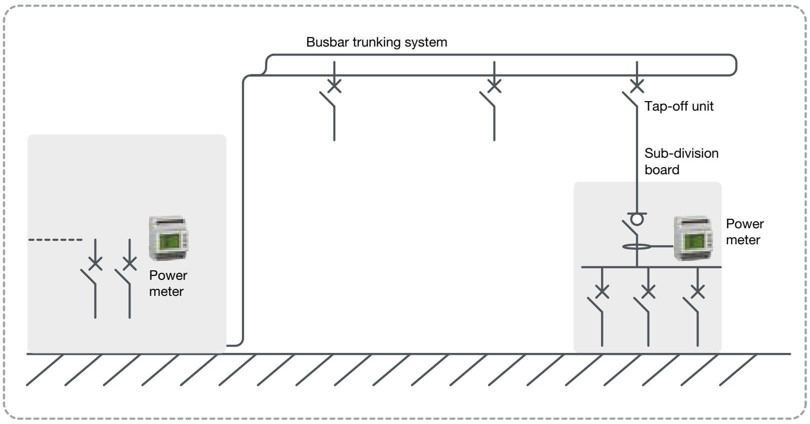
1. Feeder or incoming instrumentation for electric switchboard

For electric 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 communication cable length
• Get an overview of consumption of all feeders of the Main LV switchboard in the switchboard room
• Use protection devices that embed metering to avoid external meter and CT installation, reduce cabling, and increase switchboard spare capacity.

However, in some situations it may be necessary to instrument the incomer of a sub-distribution switchboard:

• The lack of space on the main switchboard (for existing buildings)
• Multi-tenant building with sub-billing; meters should then be installed on each floor/tenant panelboard, so that the tenant can access the meter
• An electrical distribution with a busbar trunking system for easy access to meters and, generally, due to a lack of space in the tap-off unit.



2. Integrated or independent metering panelboard

The metering devices can be installed on the switchboard or on an external metering panelboard when requested or when space is limited (existing buildings). These considerations can have an impact on the type of meter to use (embedded or separate metering).

4.3.3 Summary table

Once the metering points have been determined, this table should be completed.

	Performance metric	Static data	Dynamic data	Recording frequency	Measurement method	Meters	Location
		Data required to build performance metrics		Metering point			
1	Building energy use intensity (kWh/m²)	Gross floor area (m²)	Building energy use (kWh)	Monthly	Use result of 3	N/A	N/A
2	Environmental impact rating (T CO_2/m²/year)	Ratio kg CO_2/kW	Electrical consumption from utility (kWh)	Yearly	Use result of 5	N/A	N/A
			Building Gas consumption (m³)	Yearly	Use result of 4	N/A	N/A
3	Building energy use (kWh)	Conversion factor from m³ to kWh	Building electrical consumption (kWh)	Monthly, daily	Use result of 5	N/A	N/A
			Building gas consumption (m³)	Monthly, daily	Use result of 4	N/A	N/A
4	Building gas consumption (m³)		Building gas consumption (m³)	Monthly, daily	Direct metering	Main gas meter	Outdoor
5	Building electrical consumption (kWh)		Electrical consumption from utility	Monthly, daily	Direct metering	Main electrical meter	Main electrical room
			Photovoltaic 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/m²/HDD and CDD)	Gross floor area (m²)	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/m²/HDD and CDD)	Gross floor area (m²)	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	Monthly, daily	Use result of 10 and 11	N/A	N/A
10	DHW energy use (kWh)	Conversion factor from m³ to kWh	Boiler gas consumption (m³)	Monthly, daily	Direct metering	Gas sub-meter for boiler	Boiler room
11	DHW load (kWh)		Boiler production (kWh)	Monthly, daily	Indirect metering	Cold water flow meter Temperature probes (supply & return)	Months
12	…	…	…	…			

4.3.4 Metering point per energy usage

Below are some guidelines to help determine metering points per energy usage, depending on the level of detail required (i.e., overall building consumption, consumption by floor, or consumption by area).

For each energy usage, we give:

- The data to gather
- The appropriate measurement method
- Usual meter locations.

4.3.4.1 Lighting

Data to collect according to granulometry of consumption:

- Overall consumption: aggregated lighting consumption data for each area
- Area consumption: consumption of the circuits supplying the area (includes energy consumed by lighting fixtures, ballast, and transformers).

Measurement method:

- Without individual control or dimmer switches: hours counter or electric meter
- With individual control or dimmer switches: electric meter.

Metering points:

- Lighting feeders or group of feeders on the electric switchboards.

4.3.4.2 Ventilation

For mechanical ventilation, fans are the main sources of energy consumption.

Data to collect according to granulometry of consumption:

- Overall consumption: aggregated consumption for each fan
- Area consumption: calculated according to floor area ratio
- Number of starts and stops.

Measurement method:

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

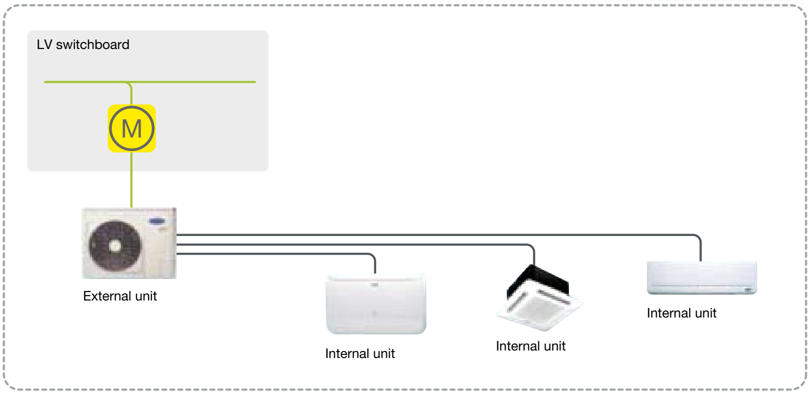
Metering points:

- Fan feeders, group of fan feeders, or VSD on the main electric switchboards or HVAC switchboards.

4.3.4.3 Heating & cooling
This energy use is the major consumer in commercial buildings.
Therefore it is strongly advisable to use direct metering to achieve accuracy.

Key
- Electrical wiring system
- Hot water pipe
- Cold water pipe
- Gas or heating oil pipe
- (M) Metering point

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 consumption: aggregations of each split system consumption
- Area consumption: consumption of the corresponding split system, which includes internal unit and external unit consumption.

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.

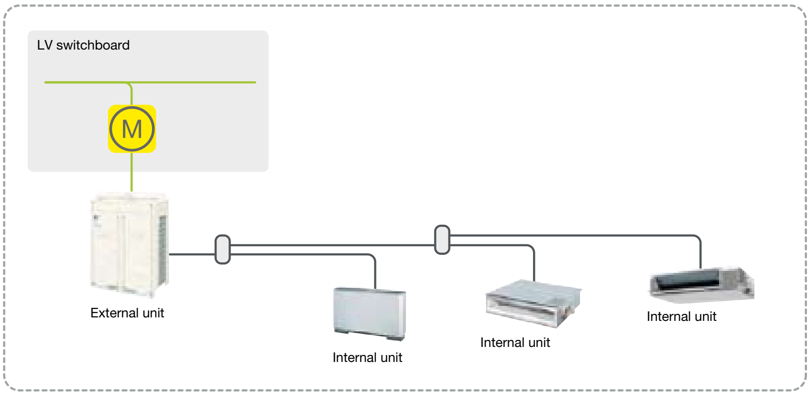
Breakdown between heating and cooling:
- Some split systems can be inverters; to break down heating and cooling consumption, an additional measurement should indicate the mode of operation, such as:
- Control signal
- Measurement of the supply and return fluid temperatures.

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

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

Principle

Electrical diagram



Data to collect according to granulometry of consumption:

• Overall consumption: aggregated consumption data for each VRF system

• Area consumption: consumption of the corresponding VRF system, which includes internal and external unit consumption.

Measurement method:

• Direct metering: electric meter.

Metering points:

• Feeders on the main electric switchboards or floor/tenant panelboard

Breakdown between heating and cooling:

There are two kinds of VRF:

• Two-pipe: all terminal units heat or cool at the same time; to break down heating and cooling consumption, an additional measurement must be taken to indicate the mode of operation:

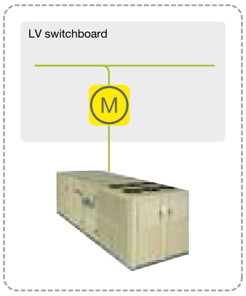
- Control signal
- Measurement of the supply and return fluid temperatures (at the outdoor unit level)

• Three-pipe: each terminal unit is independent; some units may heat while others may cool at the same time, making it difficult to get a breakdown.

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 usually used for a large open area such as a supermarket sales floor.
• Overall consumption: aggregated consumption data for each rooftop unit
• Area consumption: possible if the rooftop is used for a dedicated area, otherwise it is not possible to get an area breakdown.

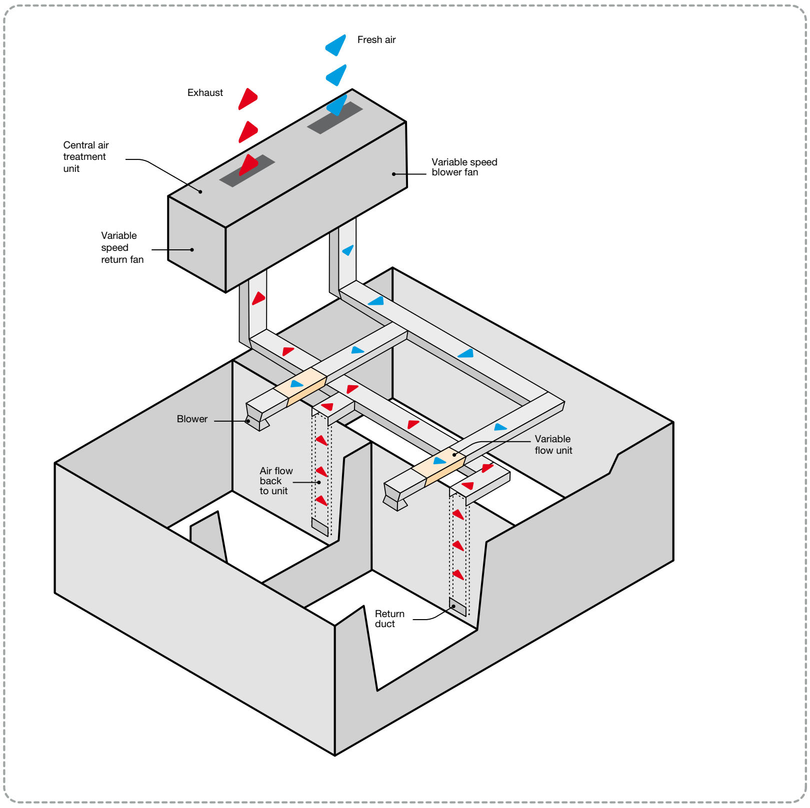
Measurement method:
• Direct metering: electric meter.

Metering points:
• Feeders on the main electric switchboards or HVAC switchboard.

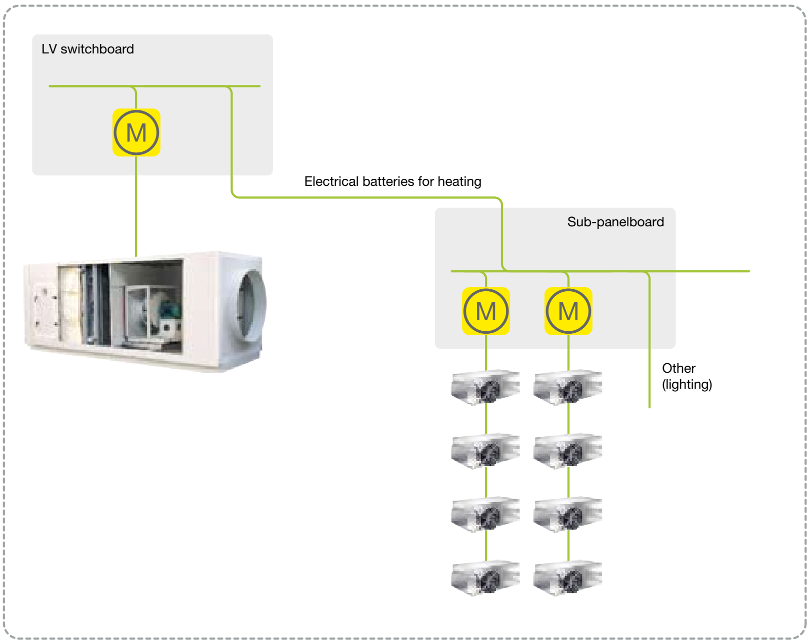
Breakdown between heating and cooling:
The rooftop provides only cooling most of the time.

4.3.4.3.4 Air system – VAV (Variable Air Volume)

Principle



Electrical Diagram



Data to collect according to granulometry of consumption:

• Overall consumption:
- AHU consumption
- Electric battery consumption for electric heating
- Boiler consumption for hot water production and pump consumption for distribution

• Area consumption: possible if the AHU is used for a dedicated area, otherwise it is not possible to get an area breakdown.

Measurement method:

• Direct metering: electric meter.

Metering points:

• Feeders on the main electric switchboards or HVAC switchboard.

Breakdown between heating and cooling:

Assuming cooling is provided by the AHU, heating can be provided in one of two ways:

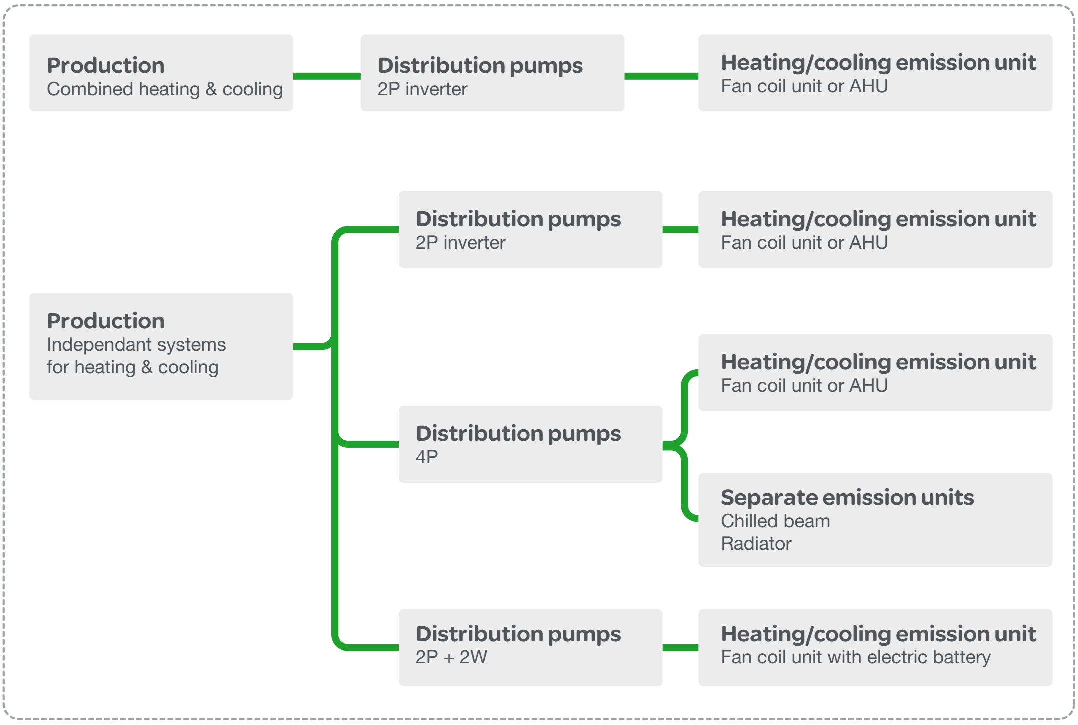
• Electric battery in each VAV terminal unit; heating consumption must then be metered at each sub-panelboard (floor or area)

• Hot water battery from a central boiler; heating consumption must then be metered at the central heating boiler via a heating meter.

4.3.4.3.5 Water system

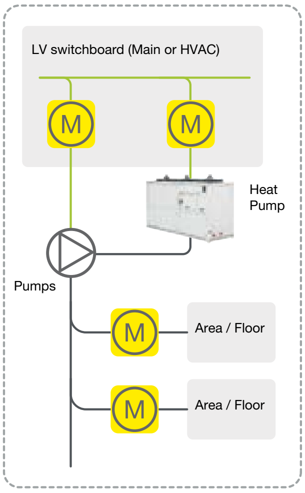
In the case of a two-pipe system (2P inverter), only heating or cooling is possible at the same time.
In the case of a four-pipe (4P) or a two-pipe, two-wire (2P+2W) system, cooling and heating can occur simultaneously.

The diagram below illustrates the different components of the system:



4.3.4.3.5.1 Combined heating and cooling system – 2 P inverter

Reversible heat pumps typically combine heating and cooling.



Data to collect according to granulometry of consumption:

• Overall heating and cooling production:
- Boiler gas consumption
- Chiller electrical consumption

• Overall heating and cooling distribution:
- Pump electrical consumption

• Area consumption: heating and cooling consumption of the dedicated area.

Measurement method:

> Heat pump consumption

• Direct metering: electric meter

> Pump distribution consumption

• Direct metering: electric meter or embedded meter in the VSD

> Area consumption

• Direct metering: heating-cooling meter; the meter is able to split heating and cooling consumption.

Metering points:

• Heat pump and pump consumption: feeders on the main electric switchboards or HVAC switchboard

• Area consumption: after the area pipe derivation, but location may depend on water distribution.

Breakdown between heating and cooling:

Overall consumption (to obtain heating/cooling breakdown):

• Use heating-cooling meter at heat pump level; this may require a communication interface (M-Bus, RS485) instead of pulse communication

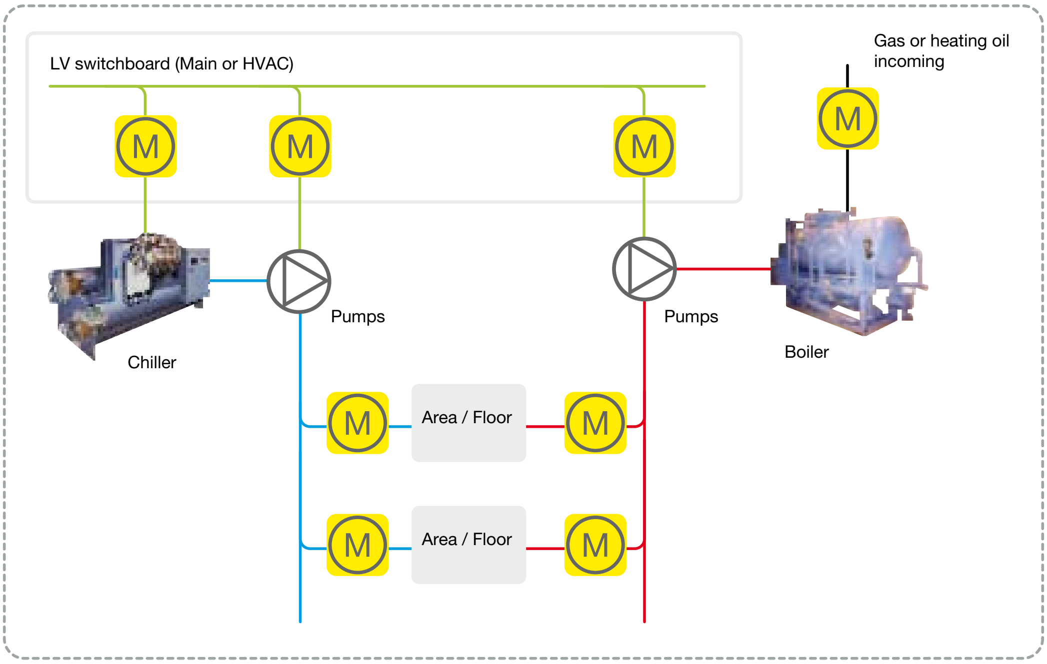
• Control signal from the heat pump controller

• Measurement of the supply and return water temperatures.

Area consumption (to obtain heating/cooling breakdown):

• Use of heating-cooling meter at the heat pump level; this may require a communication interface (M-Bus, RS485) instead of pulse communication.

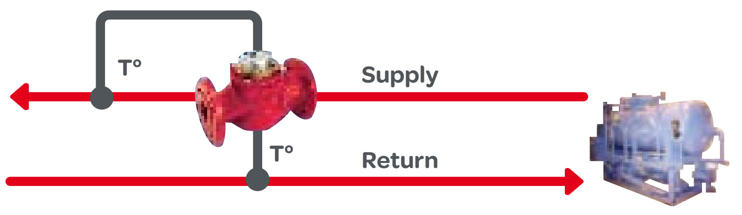
4.3.4.3.5.2 Independent heating and cooling systems – 4 P



Data to collect according to granulometry of consumption:
- Overall heating and cooling production:
- Boiler gas consumption
- Chiller electrical consumption
- Overall heating and cooling distribution:
- Pump electrical consumption
- Area consumption: heating and cooling consumption of the dedicated area.

Measurement method:

> Boiler consumption:
- Direct metering: gas or heating oil meter
- Indirect metering: heating meter boiler efficiency should be taken into account (% or m^3/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)

> Chiller consumption:
• Direct metering: electric meter.

> Pump distribution consumption:
• Direct metering: electric meter or embedded meter in the VSD.

> Area consumption:
• Direct metering: heating and cooling meters.

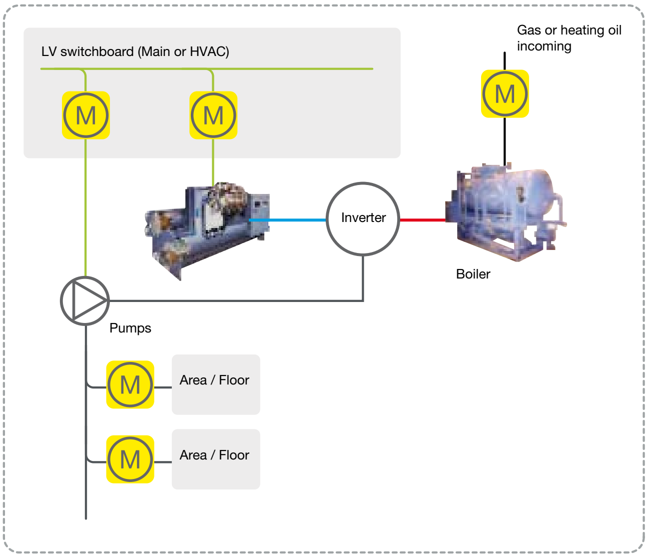
Metering points:
• Chiller and pump consumption: feeders on the main electric switchboards or HVAC switchboard
• Gas consumption for boiler: utility meter or boiler room
• Area consumption: after the area pipe derivation, but location may depend on water distribution.

Breakdown between heating and cooling:
With 4P distribution, heating and cooling are naturally independent.

Note

Using heating meters to measure both incoming gas consumption and heating production is an effective way to check boiler efficiency, which can evolve over time.

4.3.4.3.5.3 Independent heating and cooling systems – 2 P inverter



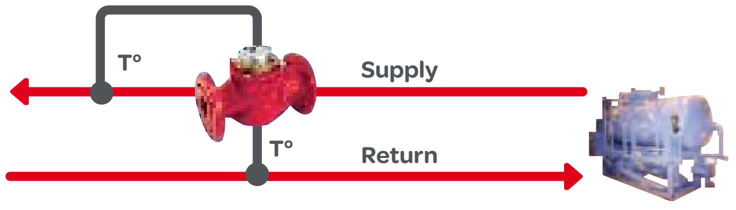
Data to collect according to granulometry of consumption:

- Overall heating and cooling production:
- Boiler gas consumption
- Chiller electrical consumption
- Overall heating and cooling distribution:
- Pump electrical consumption
- Area consumption: heating and cooling consumption of the dedicated area.

Measurement method:

> Boiler consumption

- Direct metering: gas or heating oil meter
- Indirect metering: heating meter; boiler efficiency should be taken into account (% or m^3/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)

Note

Using heating meters to measure both incoming gas consumption and heating production is an effective way to check boiler efficiency, which can evolve over time.

> Chiller consumption:
• Direct metering: electric meter.

> Pump distribution consumption:
• Direct metering: electric meter or embedded meter in the VSD.

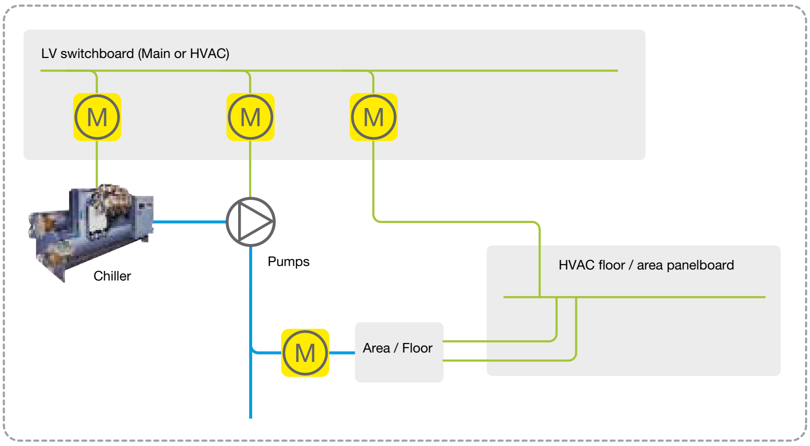
> Area consumption:
• Direct metering: heating-cooling meter; the meter is able to split heating and cooling consumption.

Metering points:
• Chiller and pump consumption: feeders on the main electric switchboards or HVAC switchboard
• Gas consumption for boiler: utility meter or boiler room
• Area consumption: after the area pipe derivation, but location may depend on water distribution.

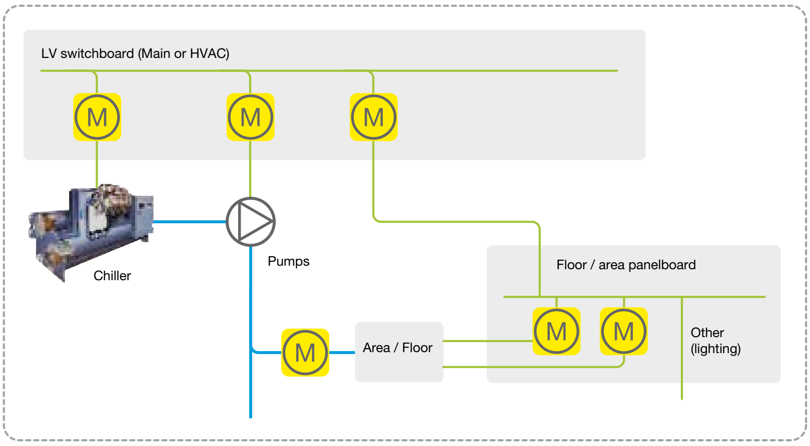
Breakdown between heating and cooling:
Overall consumption: heating and cooling production are independent.
Area consumption (to obtain heating/cooling breakdown):
• Use of heating-cooling meter; this may require a communication interface (M-Bus, RS485) instead of pulse communication
• The cooling or heating mode can also be provided by the operator via the data analysis system.

4.3.4.3.5.4 Independent heating and cooling systems – 2P+2W
The location of the heating metering point depends on either there being independent floor HVAC panel boards for electricity or floor panel boards that combine lighting, HVAC, and office equipment.

Independent HVAC floor panel



Non-independent HVAC floor panelboard



Data to collect according to granulometry of consumption:
• Overall cooling: chiller electrical consumption
• Overall cooling distribution: pump electrical consumption
• Overall heating: aggregated consumption data for electric battery consumption of each area
• Area consumption:
- Heating: electric battery consumption of the dedicated area
- Cooling: cooling consumption of the dedicated area.

Measurement method:
> Electric battery consumption
• Direct metering: electric meter.
> Chiller consumption
• Direct metering: electric meter
> Pump distribution consumption
• Direct metering: electric meter or embedded meter in the VSD.
> Area consumption
• Direct metering: electric meter for heating.

Metering points:
• Chiller and pump consumption: feeders on the main electric switchboards or HVAC switchboard
• Electric battery consumption:
- Independent HVAC floor panelboard: feeders on the main electric switchboards or HVAC switchboard
- Multi energy use floor panelboard: feeders on the main electric switchboards or HVAC switchboard
• Area consumption: cooling meters have to be installed at the floor level in the technical room.

Breakdown between heating and cooling:
Heating and cooling production are independent.

Note

Electric batteries can sometimes be used as boosters in FCUs and combined with central water heating. A heating metering point should then be added depending on whether production is combined or independent.

4.3.4.4 Domestic hot water

The following points must be considered when choosing meter locations:

• DHW production: primary energy used to heat the water
• DHW load: thermal energy delivered to the distribution system; this represents DHW demand.

The following equation can be used to find the relationship between these two values:
DHW production = heating system efficiency x DHW load.

Heating system efficiency is calculated according to boiler efficiency and loss in the hot water storage tank.

4.3.4.4.1 Independent electric boiler

Data to collect according to granulometry of consumption:
> **Overall consumption:** aggregated consumption data for electric boiler for each area
> **Area consumption: boiler feeder** consumption.

Measurement method:
• Direct metering: electric meter.

Metering points:
• Feeders on the sub-electric switchboards.

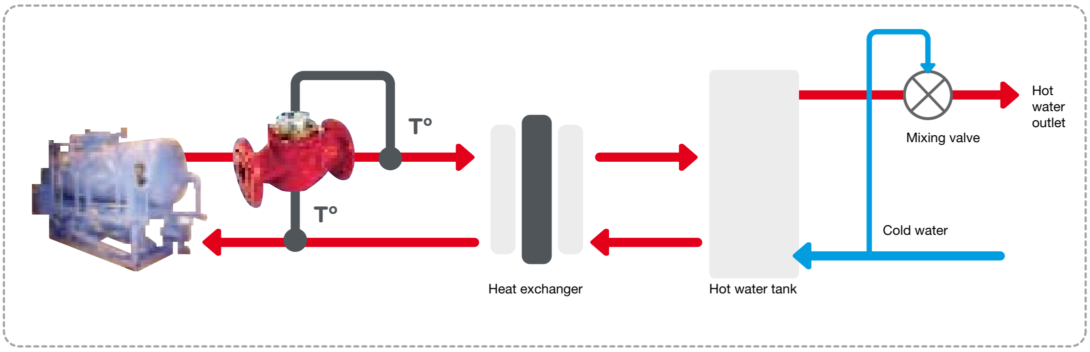
> Note
> An hours counter cannot be used as most boilers include their own control.

4.3.4.4.2 Independent central gas boiler

Data to collect according to granulometry of consumption:
• Overall consumption: gas boiler consumption and pump consumption
• Area consumption: difference between the supply flow and the return flow for the dedicated area.

> Note
> System may or may not use recirculation.

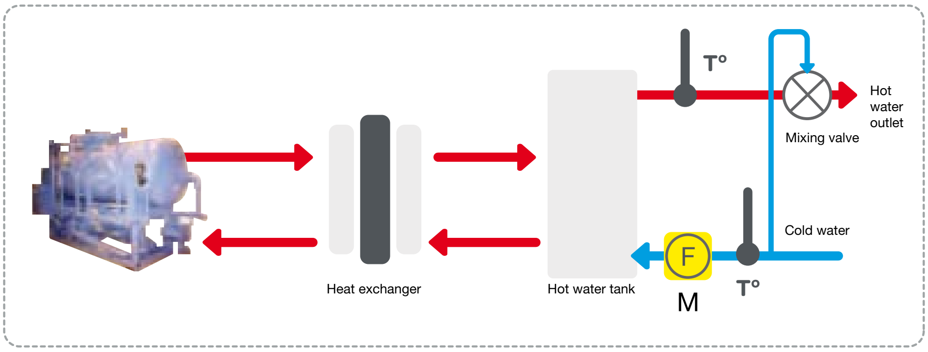
Measurement method:
> Boiler consumption:
• Direct metering: gas meter
• Indirect metering:
- Solution 1: Heating meter at the primary circuit; boiler efficiency must then to be taken into account to calculate primary energy consumption.



- Solution 2: In an existing building, hot water temperature (should be above 50°C to prevent legionella), cold water temperature, and cold water flow (leakage detection) are usually already metered downstream from the hot water tank. It is then possible to calculate the DHW load with the following formula:

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

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



> Pump consumption:
• Direct metering: electric meter.
> Area consumption:
• Direct metering: flow meter at the pipe derivation
• Indirect metering: Measure hot water pipe temperature for the corresponding area. Each time a run-off is observed, the temperature of the pipe for the area using the hot water rises. The corresponding water consumption and energy consumption metered at the overall level can then be allocated to that area. This method is only appropriate if consumption for each area does not occur at the same time. It would not be appropriate for a hotel, for instance.

Metering points:
• Boiler consumption: boiler room.
> Area consumption:
• After the pipe derivation, but location may depend on water distribution.

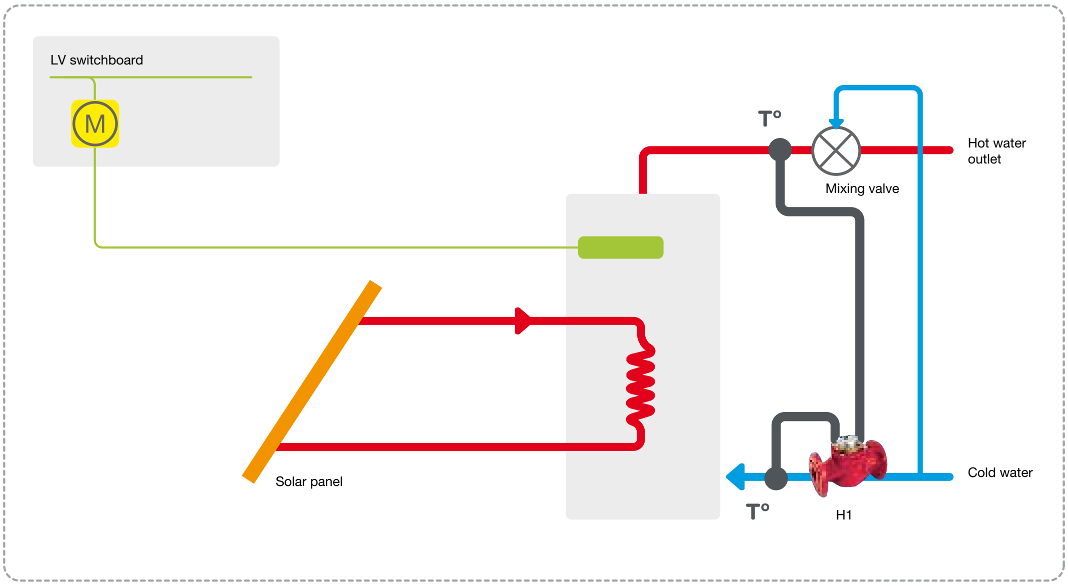
4.3.4.4.3 Combined with space heating

Indirect metering is the only way to separate space heating from DHW production. The solutions described in the previous paragraph can be used, but the heat meter should be installed on the DHW distribution pipe system.

4.3.4.4.4 Solar heating

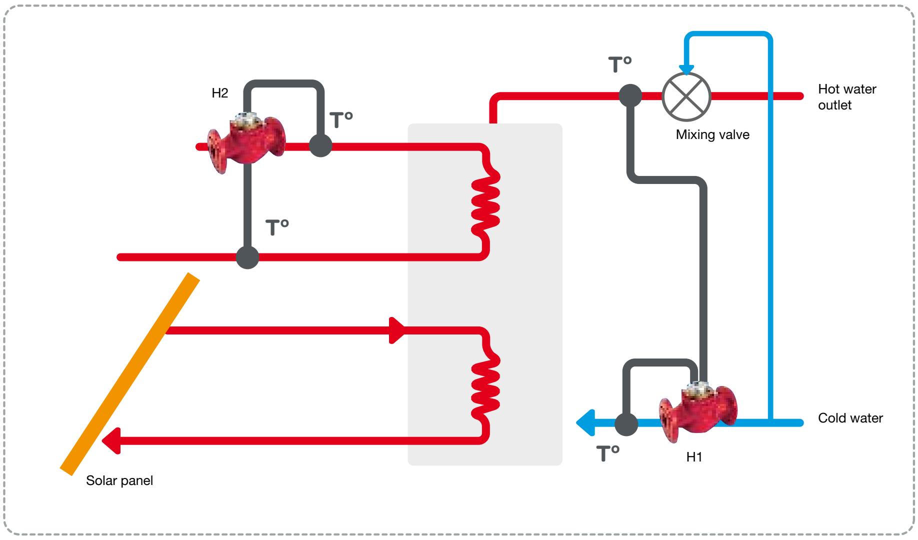
Some certifications or standards require measuring renewable energy production separately, so as to be able to split the DHW produced by solar heating from that produced by the heating booster.

4.3.4.4.4.1 With electric booster



DHW load = Heat meter H1 data (kWh)
DHW production = Electric 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)

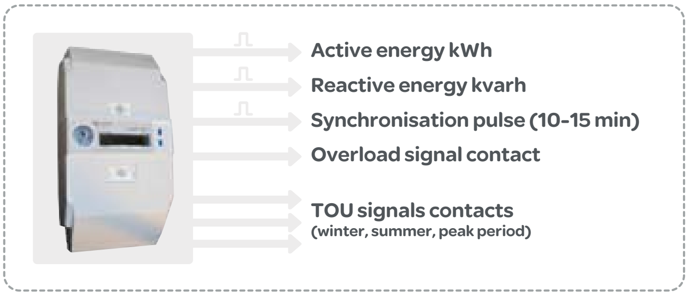
4.4 Reusing existing main meters

4.4.1 Main electric meters

The 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 bills and take advantage of low rate periods
- Billing base synchronisation (typically every 10 or 15 minutes)
- Overload signal.

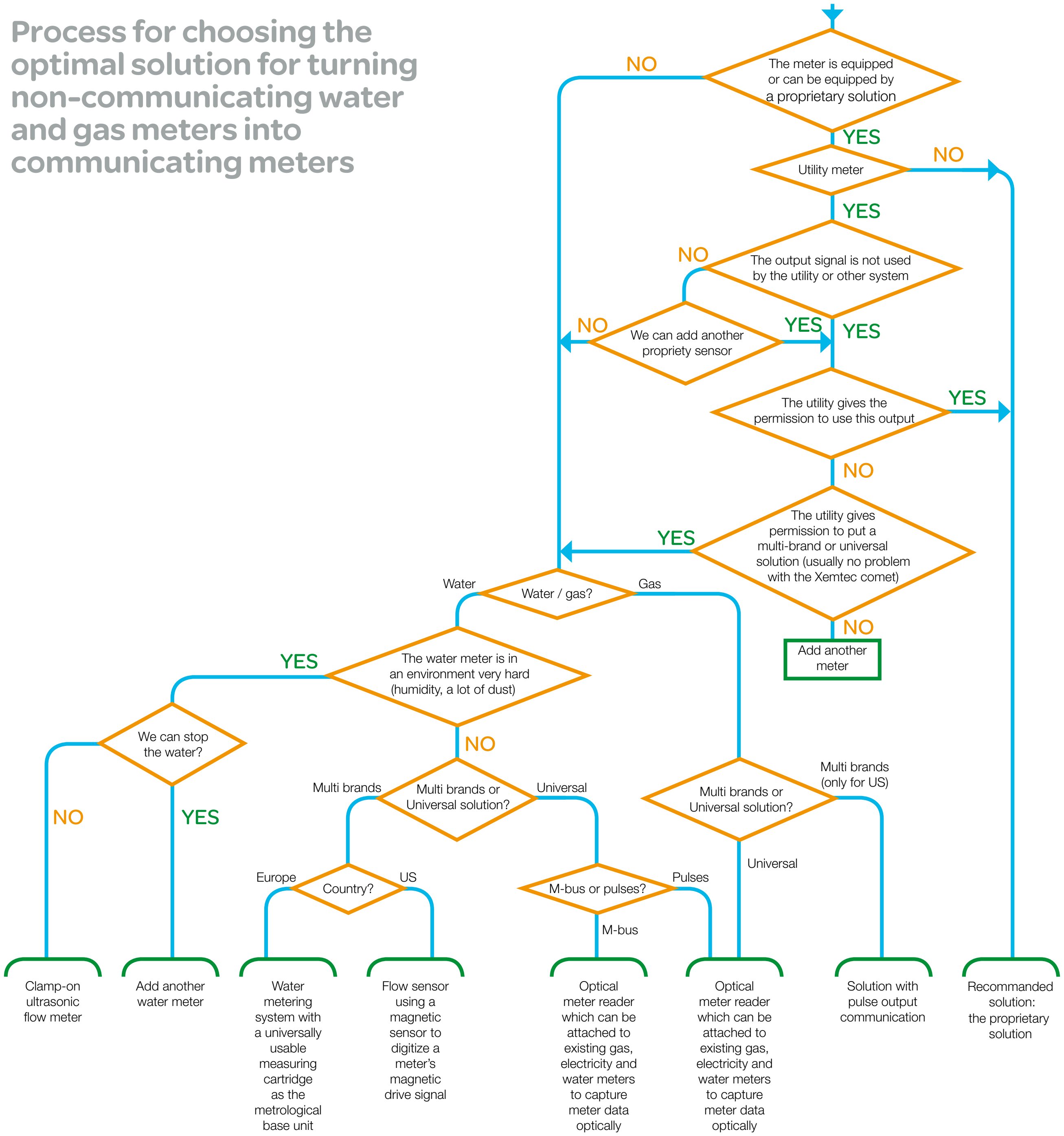
There are usually pulse or contact outputs on the meter to gather the data; if not, a new incoming meter should be installed.



4.4.2 Water and gas meters

Gather data from existing water and gas meters.

Process for choosing the optimal solution for turning non-communicating water and gas meters into communicating meters



For more information on communicating water and gas meters, please refer to Schneider Electric's Water and Gas Meter Recommendation Guide.

4.5 Selecting additional meters

4.5.1 Electric meters

Calculating energy consumption requires voltage and current measurements. In addition, many other parameters that may not be part of energy management but that are important for the building operator are based on these two values. Voltage and current measurements are also important factors to consider when selecting an electric meter, as they are generally measured by the same meter.

4.5.1.1 Criteria

Meter characteristics will vary according to project goals; here we provide the main criteria for selecting the best type of meter.

4.5.1.1.1 Data for energy management

There are two main types of meters; each handles a different type of data.

- Energy meters
- Power meters.

Energy meters are used for basic energy management, as they measure kWh and feature an optional communication output. Power meters measure active and reactive energy consumption, 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
- Load profile.

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

This data provides a deeper understanding of how the electrical distribution system is operating and helps maintenance avoid failures or restore power quickly in the event of a failure. Depending on how critical a process is, the chosen metering device should be able to generate and report some of this data.

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

• Cold generators in big-box supermarkets: alarming when power is cut
• Sensitive loads like IT servers: harmonics issues need to be monitored and analysed to avoid nuisance tripping and to separate harmonics sources from these loads .

Data necessary for installation monitoring and PQ measurement:

• Switchgear status
• Electric parameters with maximum and minimum values (voltage, current, power)
• Alarms and event time stamping for 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) are a good solution if the energy metering features meet requirements.

4.5.1.1.3 Requirements for specific applications like sub-billing or shadow metering

Applications such as sub-billing or shadow metering have specific requirements.

Sub-billing:

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

Shadow metering:

• Accuracy: identical to the utility meter (at least class 0.2); advanced energy metering.

4.5.1.1.4 Local or remote reading

All meters feature graphical displays for local reading. This ensures that operations managers get the data at the right location.

For several reasons, such as the different types of data to gather or the need for constant consumption monitoring, the metering device must be equipped with a communication output. The type of communication is also a factor when selecting the device:

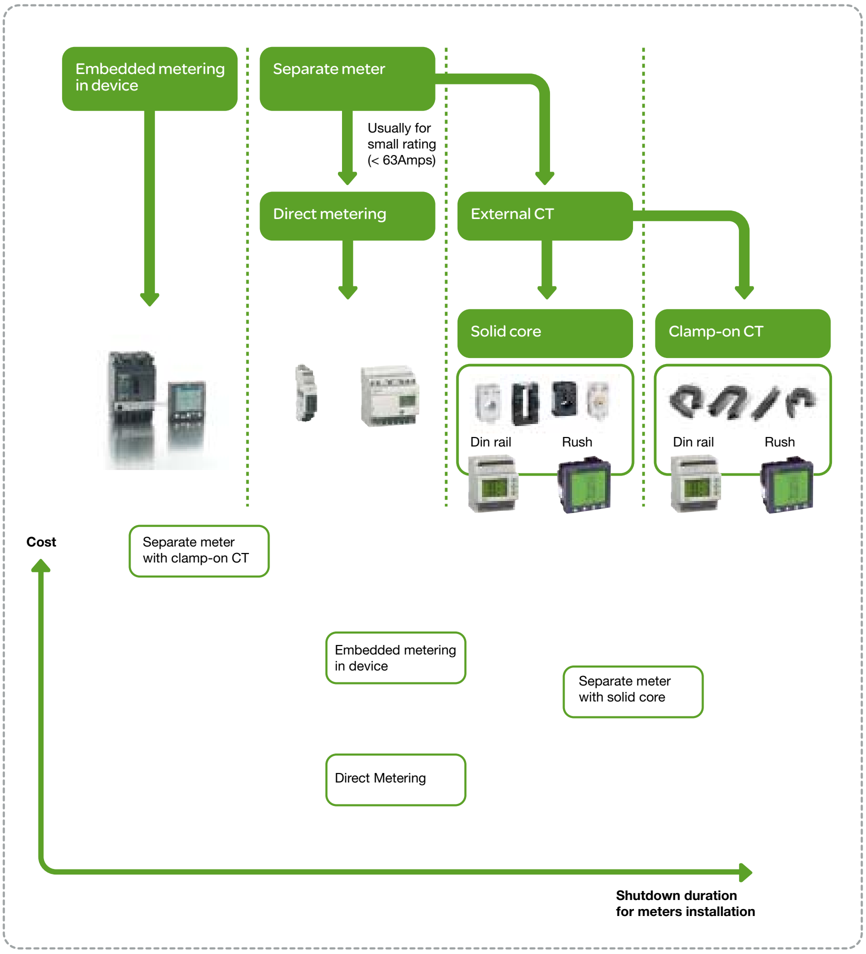
• Pulse: must be integrated into a pulse concentrator (a dedicated product or PLC), which converts pulses into energy data and stores the data in a local data log. The recording frequency must also be taken into account (see 5.1.1), as the number of pulses per kWh may differ from one device to another.
• Communication protocols such as Modbus, Ethernet or M-Bus. Data are transferred to an EMS (Energy Management System) or BMS (Building Management System) to be aggregated, normalised, and analysed.

4.5.1.1.5 Installation mode and shut down time

Due to difficulty installing current transformers (CT) or limited space on the switchboard, installation and shut down times can be very high, especially for existing buildings. Therefore, this is an important factor when selecting the following metering devices and types of installation:

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

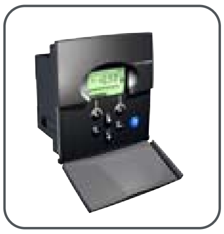
The different types of meter installation:



Embedded or separate metering

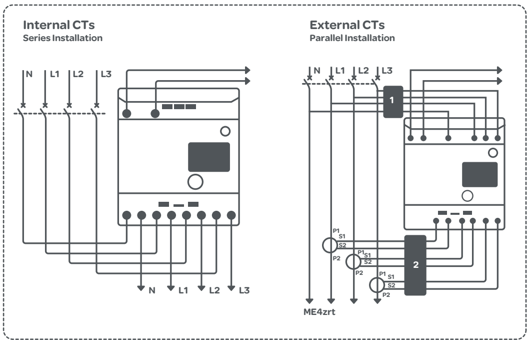
More and more devices installed in buildings feature embedded electronics with communication capabilities. As soon as their core function needs current metering, they are able to calculate energy consumption data. Compared to independent meters, these devices don't require additional external CTs. In general, these CTs (and VTs in some cases) are chosen for features like protection, for example. These devices are generally not as accurate as power meters, and do not provide advanced metering features.

Some examples of Schneider Electric devices

Circuit breakers with electronic trip units	Speed drives	Varmeter controllers
		
Compact NSX equipped with Micrologic-E trip unit	Altivar 21	Varlogic-N

Direct measurement or external CTs

When a separate meter is used, it can be equipped with internal CTs that will facilitate installation on the switchboard, as there is no need for CT cabling or meter protection. Internal CTs are available for EN40-type energy meters (kWh only) and ME-type meters up to 63A.



Clamp-on current transformers

When continuity of service is required in an existing building, clamp-on current transformers can be used, eliminating the need to disconnect the circuit being measured and the need to thread a wire through the CT opening. For these reasons, clamp-on CTs work best for crowded electrical panels. These CTs cost more than solid-core CTs (around five times more).

Solid core

Clamp-on

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 with easy access for operation and maintenance via a cut-out in the door

• DIN rail: the meter is mounted directly on the rail on the switchboard; this requires available space on the switchboard and, preferably, a transparent door.

4.5.1.2 Main guidelines for a commercial building

The diagrams and table below are designed to help select the right meters for your electrical architecture, current ratings, and load or feeder sensitivity. Sensitive feeders need special attention in terms of power quality and electrical distribution monitoring.

However, each project should be considered in light of the network configuration and customer needs.

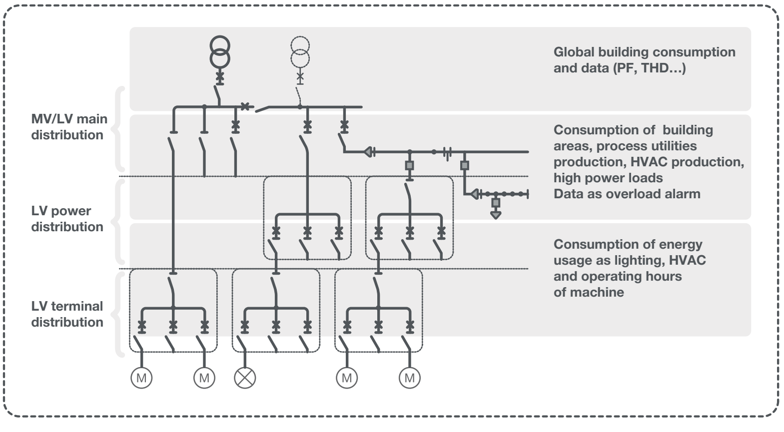
4.5.1.2.1 Needs

The category of the metering device will generally depend on where it is installed in the electrical distribution system:

• Metering devices that are installed at the installation's main supply should allow:
- Analysis of building power demand (load profile) and peak demand (value and duration)
- Verification of energy bills and penalties (reactive consumption and overload)
- Analysis of power quality such as harmonic distortion.

• Metering devices that are installed at the main low voltage switchboard feeder (or at the sub-distribution switchboard feeder) should allow:
- Sub-metering (consumption monitoring of building areas or processes) for cost allocation
- Consumption monitoring for building utilities such as Air Handling Units, boilers, chillers or other major energy usages for:
> Energy usage analysis
> Building benchmarking
> Standards or certifications
> Building control optimisation
> To improve maintenance with alarms.

• Metering devices that are installed closest to the point of consumption should allow:
- Energy use breakdowns as requested by some standards and certifications, or to enable building benchmarking
- Energy consumption monitoring for:
> Energy usage analysis
> Building management optimisation
- To determine the number of operating hours of a machine or motor.



Main electric supply

• Rating current < 630 Amps

Metering devices that are installed at the main supply should provide common data for the whole installation:
- Overall active and reactive energy consumption with the overall power factor
- Harmonic distortion (THD) to check the network power quality
- Overload alarming and min/max power/voltage/current to monitor overall energy consumption and maintenance.

• Rating current > 630 Amps

In addition to the previous requirements, it is advisable for this rating to:
- Limit uncertainty by selecting a meter with 0.5 class accuracy and that allows energy bill verification
- Be able to perform event analysis for maintenance (meter with event stamping)
- Obtain the load profile and 10mn synchronisation with the utility meter for contract optimisation purposes
- In big-box store, for instance, due to the substantial lighting, IT, and TV department consumption, harmonic distortion could be high; a detailed harmonics analysis should be performed to determine the best filtering solution to reduce harmonics.

Renewable energy production

• Photovoltaic

A simple energy meter is sufficient to measure energy production.

• Wind

When wind speed is low, the generator can be used as a 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 poor utility reliability, it may be useful to measure the energy produced as the energy cost and related CO_2 emissions are significant due to heating oil consumption.
A simple energy meter is generally sufficient to measure energy production.
However, data such as voltage and current can be useful for alarming.

Sub-distribution board feeders

• Rating current < 630 Amps

Active and reactive power to more easily identify sources of reactive power consumption.
Phase current to detect unbalanced phases.

• Rating current > 630 Amps

In addition to the previous requirements, it is advisable for this rating to:
- Limit uncertainty by selecting a meter with 0.5 class accuracy
- Check harmonic distortion; this will facilitate analysis for the identification of harmonics sources
- Measure neutral current to detect overloads on the neutral conductor (third-order harmonics due to non-linear single phase)
- Monitor energy consumption and maintenance with overload alarming and min/max power/voltage/current; this is especially important if the process evolves over time, such as for the implementation of new equipment on a production line for an industrial building.

Applications such as tenant sub-billing require accuracy of 1% and data logging to avoid data loss in the event of power outages or problems with communication devices. For cost allocation, 2% accuracy is sufficient.

Special feeders on the main switchboard

"Special" refers to feeders that supply:
• Critical loads that cannot be interrupted; or those that can tolerate only short interruptions (such as cash registers in a supermarket)
• Loads like motors with Variable Speed Drives or lighting (high power feeder in a big-box supermarket, for example) that may disrupt sensitive loads.

For these feeders, energy metering should be combined with installation and power quality monitoring (measurement of electric parameters with harmonic analyses and data used to reduce curative maintenance and facilitate preventive and predictive maintenance).

• Rating current < 63 Amps

- Main electric parameters to check the proper performance and power supplies of the load
- Communication capabilities in case of load malfunctions.

• Rating current < 630 Amps

In addition to the previous requirements, it is advisable for this rating to gather the following data:
- Harmonic distortion for loads that produce harmonics (motors, lighting, IT servers). For motors in particular, harmonic distortion may reveal problems, as the current is a direct reflection of motor operation; this can help with preventive maintenance
- Overload alarming and min/max power/voltage/current to monitor energy consumption and maintenance for sensitive loads
- For high harmonic producers, the neutral current has to be measured to detect overloads on the neutral conductor.

• Rating current > 630 Amps
In addition to the previous requirements, it is advisable for this rating to:
- Limit uncertainty by selecting a meter with 0.5 class accuracy and that allows energy bill verification
- Be able to perform event analysis for maintenance (meter with event stamping)
- Obtain the load profile and 10mn synchronisation with the utility meter for contract optimisation purposes.

Special feeders in a sub-distribution board
• Rating current < 63 Amps
- Energy consumption
- Main electric parameters to check proper performance and power supplies of the load.

• Rating current < 630 Amps
- Communication output to generate alerts in the event of malfunctions.

Common feeders
> Rating current < 63 Amps
A simple energy meter is sufficient for measuring energy consumption.

> Rating current < 630 Amps
In addition to the previous requirements, it is advisable for this rating to gather the following data:
• Main electric parameters (voltage, current) to check 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 gather the following data:
• Communication capabilities in case of load malfunctions.

4.5.2 Non-electric meters
For non-electric meters, we recommend referring to the corresponding manufacturer or to the following documents, which give an overview of flow meter technologies and advice for selection:
• Selecting the Right Flowmeter, Corte Swearingen
• Chapter 5 of Metering Best Practices: A Guide to Achieving Utility Resource Efficiency, US Department of Energy, October 2007.

5 Case study

A 5,000m^2 mid-range chain hotel with 200 guest rooms

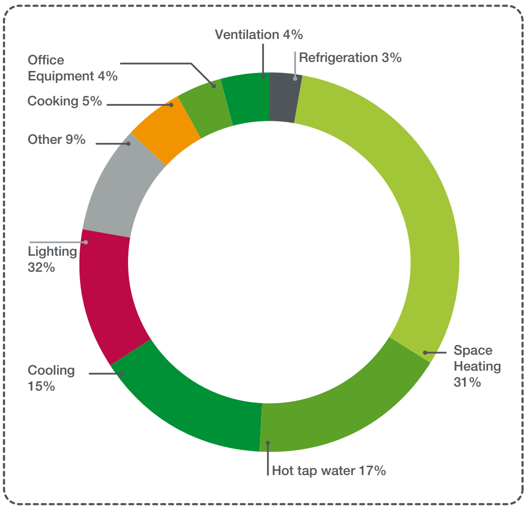
5.1 Objectives

The main objectives of the corporate energy manager are to perform building benchmarking and understand how each hotel operates in order to make recommendations to the hotel director concerning relevant energy conservation measures.

5.2 Performance metrics

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

For this case study, we will focus on mid-range hotels belonging to a single hotel chain. In this type of hotel, the main sources of energy consumption are heating, cooling, domestic hot water, catering, and lighting. The main factors that impact consumption are the number of rooms, the weather, and occupancy rates (or number of overnight stays). Therefore, these factors should be used to normalise the data to ensure that comparisons between hotels are consistent.



The following performance metrics must be determined to meet the objectives stated above:

1. Whole building energy use intensity (EUI) kWh/m² and kWh/occupancy level
2. Whole building electricity EUI kWh/m² and kWh/occupancy level
3. Whole building gas EUI m³/m²/HDD and CDD (heating degree days and cooling degree days); mainly used for heating and domestic hot water
4. Whole building water use m³/occupancy level
5. Whole building electrical consumption breakdown by time of use (TOU)
6. Whole building electrical power demand kWh with identification of over demand periods
7. Whole building reactive energy consumption
8. Whole building space heating EUI kWh/m²/HDD and CDD
9. Whole building domestic hot water EUI (production) kWh/m² and kWh/occupancy rate
10. Whole building domestic hot water volume m³/m² and m³/occupancy level
11. Total cooling consumption EUI kWh/m²/HDD and CDD
12. Total ventilation EUI kWh/m²
13. Kitchen electrical consumption kWh
14. Kitchen cold water consumption m³/m²
15. Lighting consumption for common areas kWh/m²

5.3 Metering points

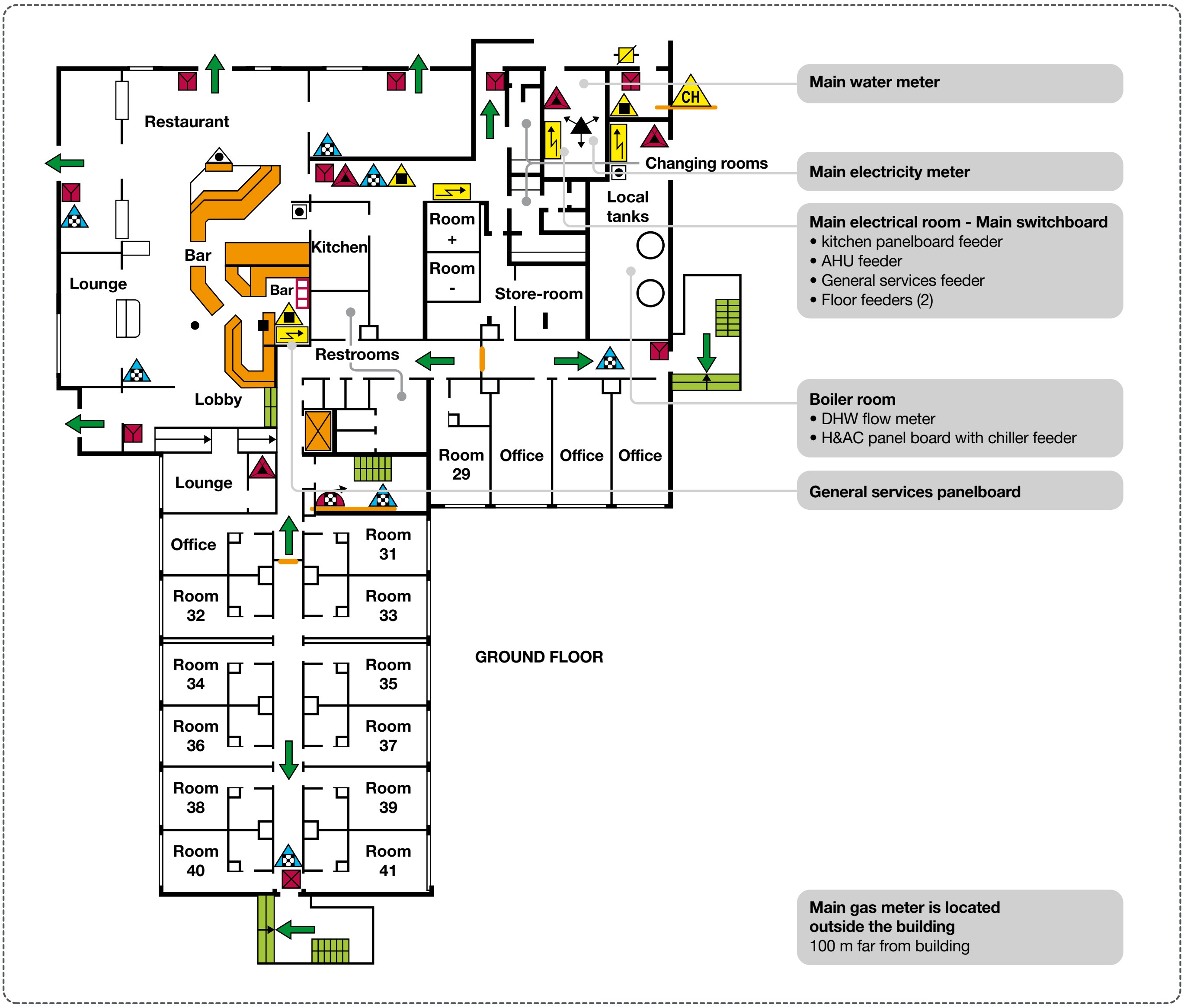
We must now identify which data are required to build the performance metrics.

	Performance metric	Static data (Necessary data to build performance metrics)	Dynamic data (Necessary data to build performance metrics)
1	Whole building EUI (kWh/m² and kWh/occupancy level)	Gross floor area (m²) kWh/m³ ratio for gas	Building electrical consumption (kWh) Building gas consumption (m³) Occupancy level
2	Whole building electricity EUI kWh/m² and kWh/occupancy level	Gross floor area (m²)	Building electrical consumption (kWh) Occupancy level
3	Whole building gas EUI m³/m²/HDD	Gross floor area (m²)	Building gas consumption (m³) Outdoor temperature (for HDD)
4	Whole building water use intensity m³/occupancy level		Water consumption (m³) Occupancy level
5	Whole building electrical consumption breakdown per TOU		Building electrical consumption (kWh) TOU signals
6	Whole building electrical power demand	Gross floor area (m²)	Main electric power (kW)
7	Whole building space heating EUI kWh/m²/HDD	Gross floor area (m²)	Gas consumption for space heating boiler Outdoor temperature (for HDD)
8	Whole building DHW EUI kWh/m² and kWh/occupancy level	Gross floor area (m²) kWh/m³ ratio for gas	Gas consumption for DHW boiler Water pump consumption (kWh)
9	Whole building DHW volume intensity m³/m² and m³/occupancy level	Gross floor area (m²)	Cold water volume entering the DHW system (m³) Occupancy level
10	Total cooling EUI kWh/m²/HDD	Gross floor area (m²)	Chiller consumption (kWh), water pump consumption (kWh) Outddor temperature (for HDD)
11	Total ventilation EUI kWh/m²	Gross floor area (m²)	Kitchen electrical consumption
12	Kitchen electrical consumption (kWh)		Kitchen electrical consumption
13	Kitchen water consumption (m³)		Kitchen water consumption (m³)
14	Lighting common areas EUI	Gross floor area (m²)	Lighting consumption of common areas (kWh)

At this stage, we need to consider building characteristics like locations of main incoming meters, electrical and mechanical rooms, and network distributions. This will help determine the necessary metering points. Most of the performance metrics can be built using direct metering. However, other methods are recommended for two metrics in particular:

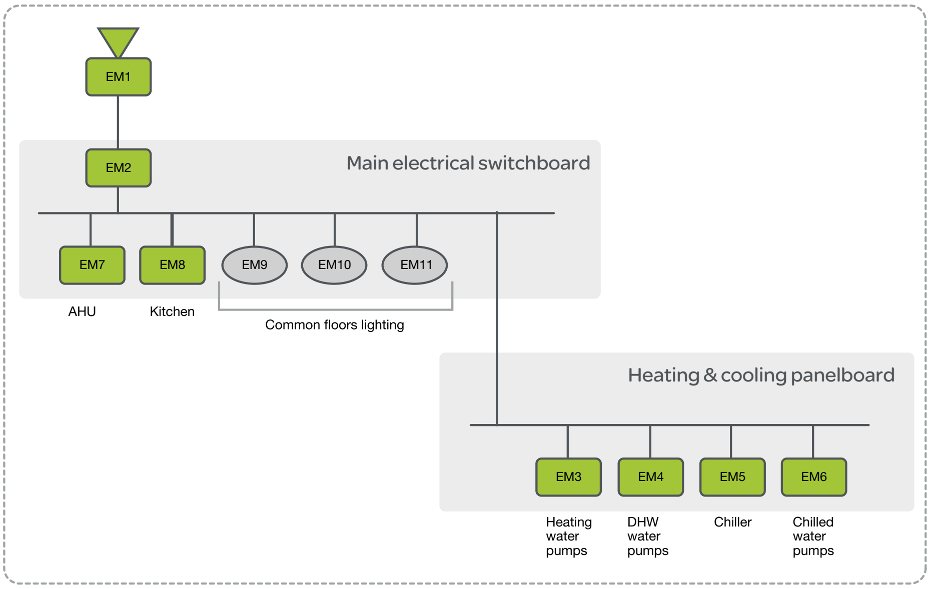
• Metering common lighting consumption with direct metering would be too costly, as it would require adding four meters to each floor panelboard to be able to separate lighting from other end-use consumption. Therefore, each panelboard's consumption is measured and common area lighting consumption determined at night.

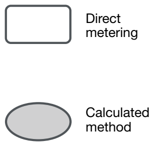
• Gas consumption for DHW boiler: as there is no gas for cooking, the difference between whole-building gas consumption and the gas consumption of the space heating boiler can be used to calculate this metric.



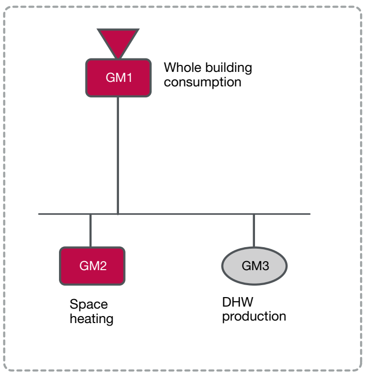
Metering diagrams with the different metering points

Electrical diagram

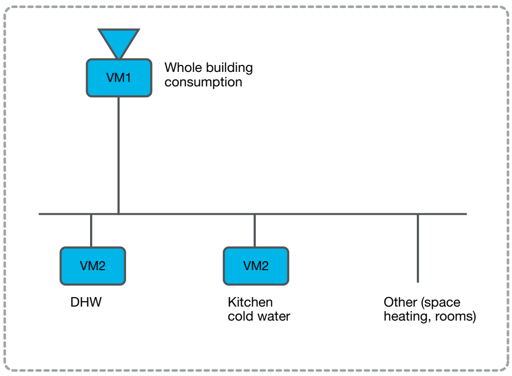




Gas diagram



Water diagram



5.4 Using existing meters

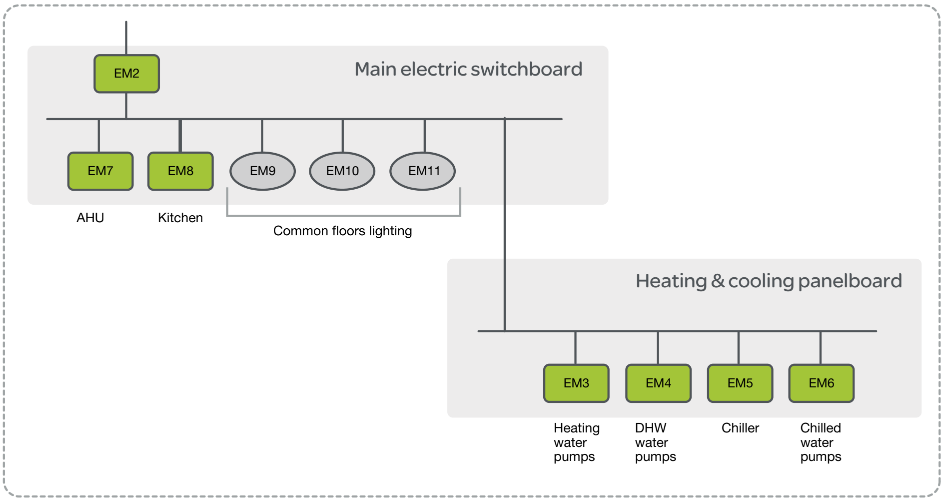
The following meters exist already and can be reused to gather the necessary data:

- Main electric 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	Main characteristics
		PM750 with clamp-on CT (only 2 hours shutdown was acceptable) or NSX circuit-breaker with Micrologic 5.2E trip-unit	EM2	< 630 amps	Active, reactive, apparent power and energies U, I, Power factor and frequency Minimum & Maximum, Alarming THD
		PM9c or NSX circuit-breaker with Micrologic 5.2E trip-unit	EM5, EM7, EM8	< 250 amps	Active, reactive, apparent power and energies U, I, Power factor and frequency
		PM9p with solid core	EM3, EM4, EM6	< 63 amps	Only kWh consumptions

	Data required to build the performance metrics		
Performance metric	**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 consumption breakdown per TOU		Building electrical consumption (kWh)	yearly, monthly, weekly, daily
		TOU signals	weekly, daily
Whole building electrical power demand	Gross floor area (m^2)	Main electric power (kW)	yearly, monthly, weekly, daily
Whole building reactive energy consumption (kvarh)		Electrical reactive energy (kvarh)	yearly, monthly, weekly, daily
Whole building space heating EUI $kWh/m^2/HDD$	Gross floor area (m^2)	Gas consumption for space heating boiler	yearly, monthly, weekly, daily
		Water pump consumption (kWh)	weekly, daily
		Outdoor temperature (for HDD)	weekly, daily
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, weekly, daily
		DHW pump consumption (kWh)	weekly, daily
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, weekly, daily
		Occupancy level	yearly, monthly, weekly, daily
Total cooling EUI $kWh/m^2/HDD$	Gross floor area (m^2)	Chiller consumption (kWh)	yearly, monthly, weekly, daily
		Water pump consumption (kWh)	yearly, monthly, weekly, daily
		Outddor temperature (for HDD)	yearly, monthly, weekly, daily
Total ventilation EUI kWh/m^2	Gross floor area (m^2)	AHU electrical consumption	yearly, monthly, weekly, daily
Kitchen electrical consumption (kWh)		Kitchen electrical consumption	yearly, monthly, weekly, daily
Kitchen water consumption (m^3)		Kitchen water consumption (m^3)	yearly, monthly, weekly, daily
Lighting common areas EUI	Gross floor area (m^2)	Lighting consumption of common areas(kWh)	yearly, monthly, weekly, daily

Metering points

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

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