Designing a metering system for small and medium-sized buildings

by Jean-Paul Genet and Cliff Schubert

Executive summary

In today's 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 a comprehensive energy management strategy. Best practices for selecting meters, and identifying metering points are described. In addition, metrics for measuring gains in energy efficiency are explained.

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Introduction

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 greenhouse gas (GHG) 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.

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 CO2 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]

Figure 1

The need for electricity in emerging economies will drive a 70% increase in worldwide demand.

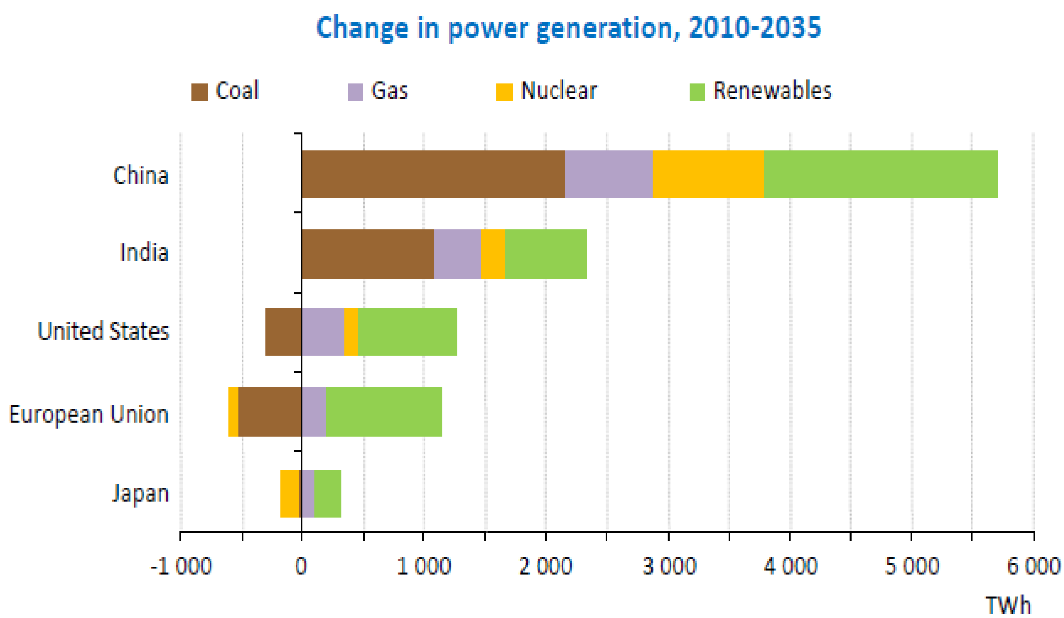

Figure 1 courtesy of International Energy Agency, World Energy Outlook 2012

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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.

Achieve energy savings of up to 30%

Active vs. 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 of 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 example, requires all new buildings to be nearly zero-energy by 2020. Still, most buildings will not meet this directive. Those 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.

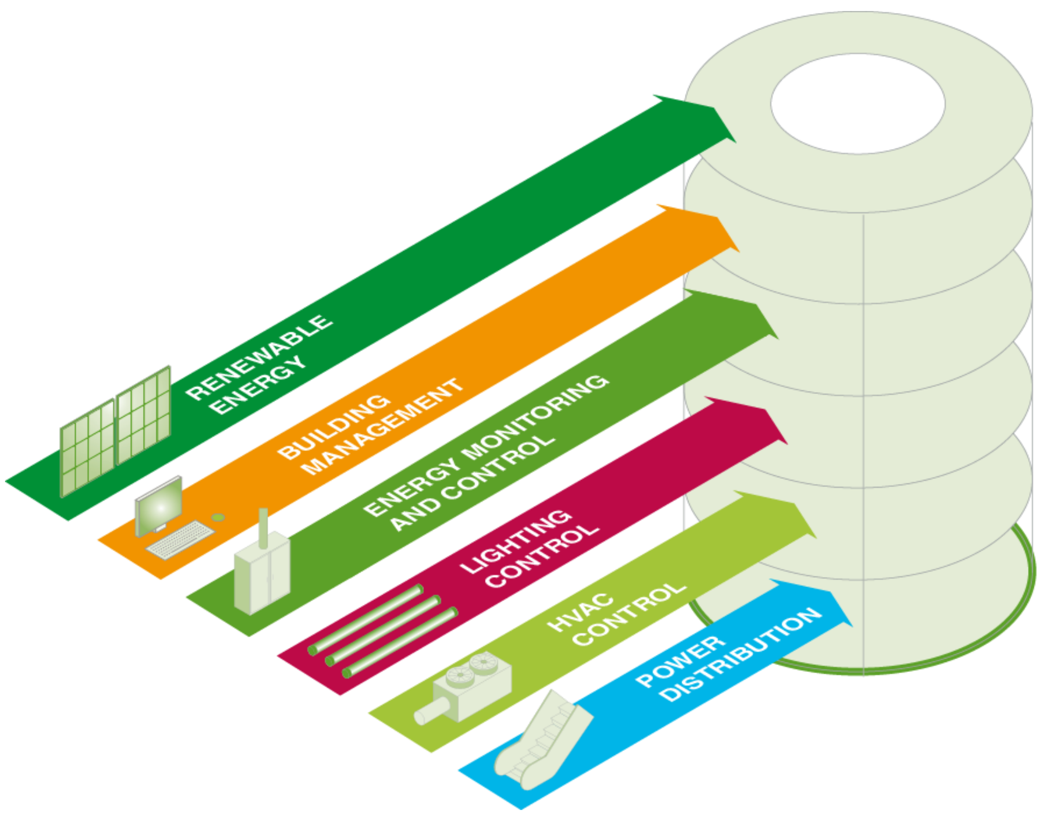


Figure 2
Energy efficiency solutions for all building applications

Automatic metering

The cornerstone of energy efficiency

Continuous automatic metering systems often use dynamic energy dashboards to display building operation and energy consumption information. 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.

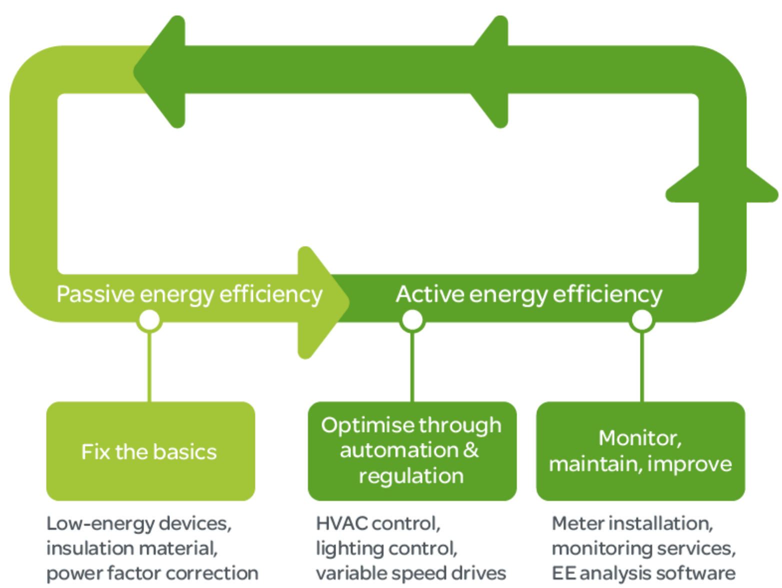
Whether a building is equipped with simple energy dashboards or is outfitted with a full-fledged automation and control system, continuous automatic metering also gives building owners, operators, and occupants access to the data they need to optimise their current electricity supply contracts or negotiate 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

Figure 3
Energy Audit & Measurement:
Continuous metering can identify new opportunities, manage demand, allocate costs and improve facility 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 conservation measure (ECM) performance against a measurement and verification metric like the IPMVP, thereby avoiding penalties and demonstrating progress toward carbon commitments.

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.

International Performance Measurement and Verification Protocol (PMVP)

The IPMVP measures and verifies the energy savings of energy-efficiency solutions:

- **Pre-installation audit:** baseline energy consumption data can be measured and calculated
- **Post-installation audit:** baseline data can be compared with post-installation consumption data to determine actual savings, drive behavioural changes, and lower costs.

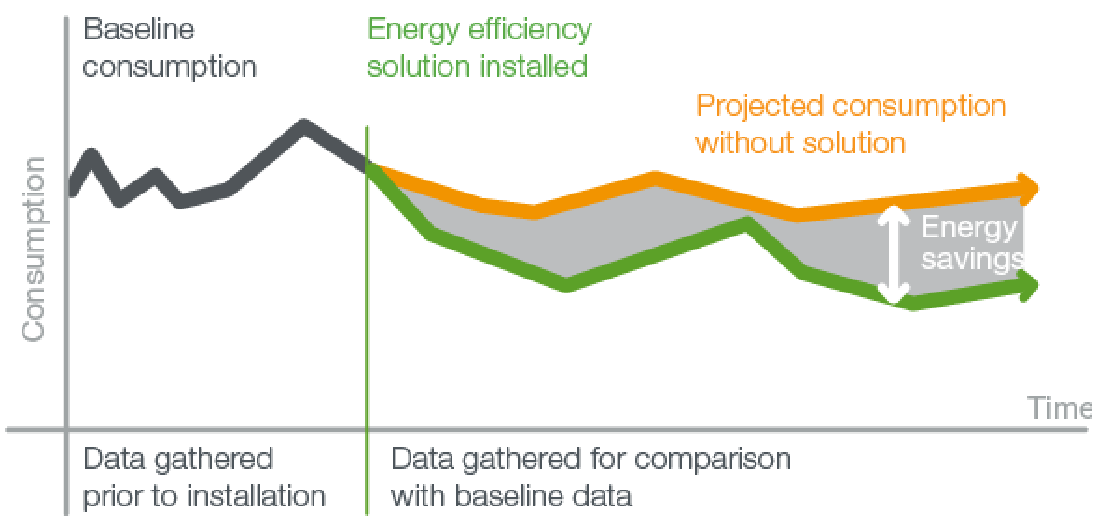


Figure 4
Measureable savings can be achieved by measuring and verifying baseline data

Methodology

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.

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

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

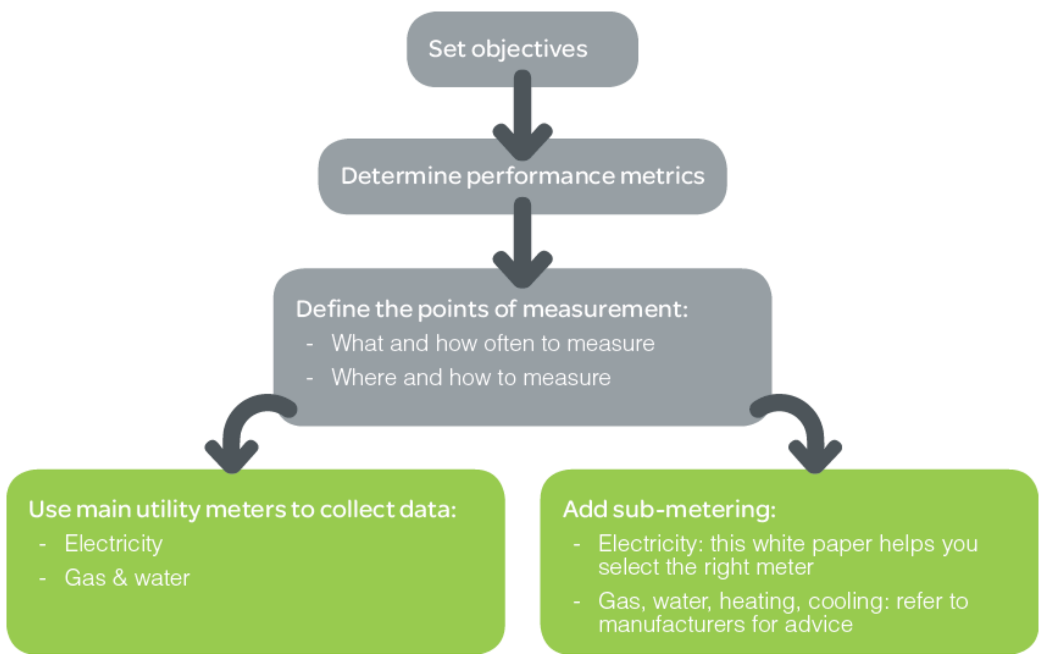


Figure 5
Steps for identifying needs and setting objectives

Cost allocation

"Measuring consumed energy consumed at different points on the network gives users the opportunity to take ownership of energy costs at the appropriate level in an organisation. It helps drive behavioural changes and lower costs."

Energy cost allocation

For buildings where cost allocation is used, energy costs are commonly formula-allocated 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 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.

Sub-billing

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

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.

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.

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.

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.

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.

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.

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.

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."

"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."

Table 1

*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 use of sub-metering either by area or energy use.*

Size of plant for which separate metering would be reasonable

Plant item	Rated input power
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 electric distribution boards	10

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.

Performance metrics for whole-building benchmarks

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 normalize consumption. 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 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.

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. 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.

Table 2

To complete your building and energy use breakdown, begin by identifying major sources of consumption with these tools:
- Energy audit
- Building benchmarking
- Simulation

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

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 & 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).

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.

'Just enough' data

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.

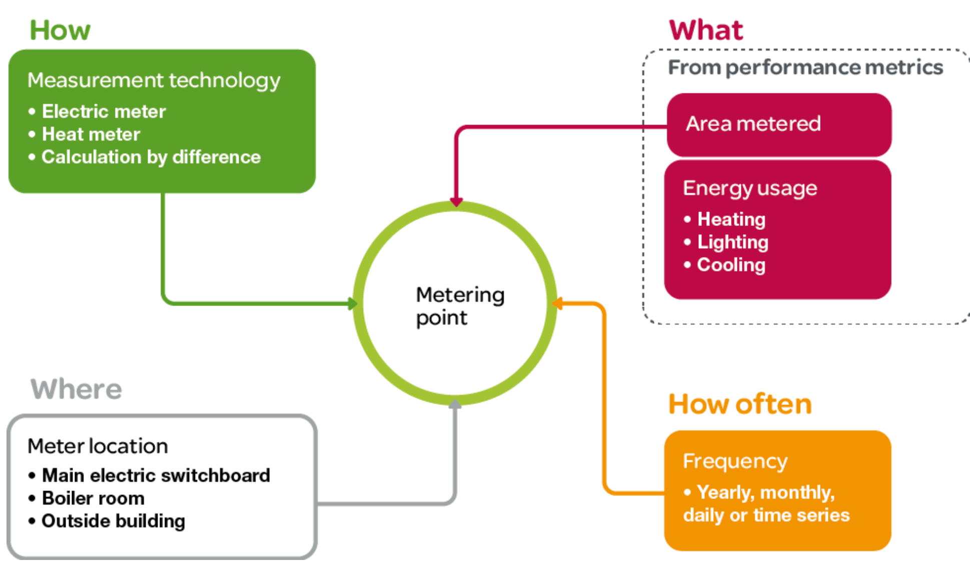
An effective metering system design must avoid the following pitfalls:

- Gathering insufficient data to enable an accurate building consumption analysis
- Gathering too much data that are never used for analysis, consuming resources better-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, considering 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?

Figure 6
Determining proper metering points involves answering the right questions



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. Data are often used to normalise measurements for benchmark comparisons.
- Dynamic data such as energy consumption, temperatures, or flows, with corresponding recording frequency. The recording frequency depends on the project goals and could be yearly, monthly, daily, or time series.

Table 3

Data required to build performance metrics

Performance metric	Static data	Building	Recording frequency
Building energy use intensity (kWh/m²)	Gross floor area (m2)	Building energy use (kWh)	Monthly
Environmental impact rating (T CO2/m²/year)	Ratio kgCO2/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

Recording frequency depends on 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, recording frequency must be compatible with tariff structure (once/day could be enough for a constant tariff but insufficient for several tariff slots /day).

- For cost allocation or building energy performance benchmarking, once a day is sufficient.

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.

Measurement method

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

Figure 7
Hours counter

Indirect metering: Readings from indirect meters can be used to measure energy consumption as illustrated at right.

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.

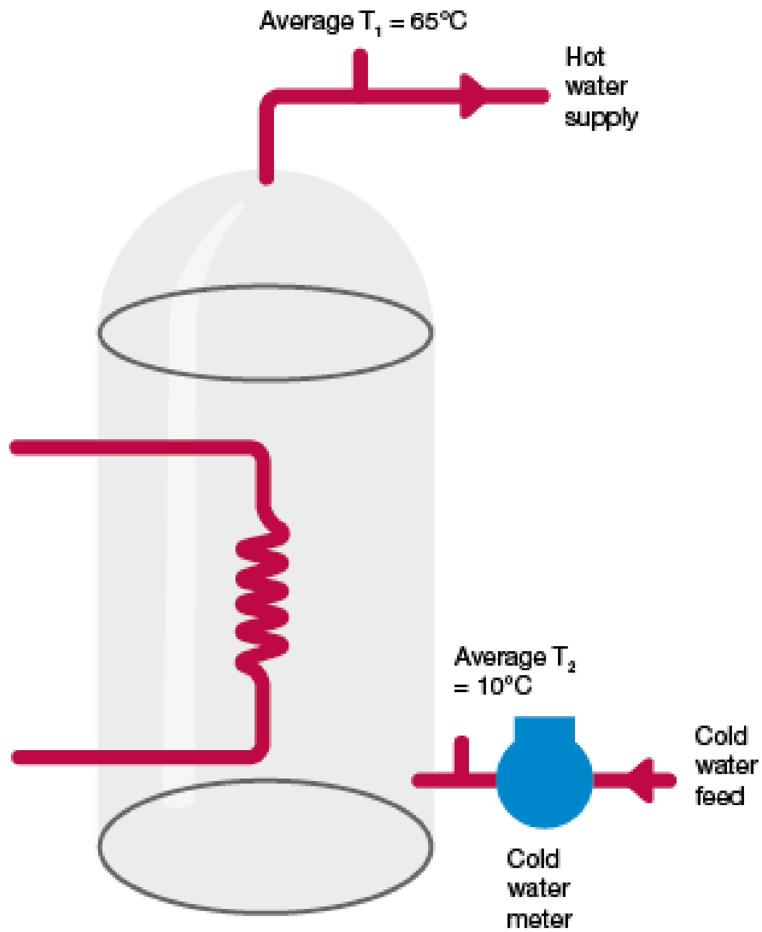


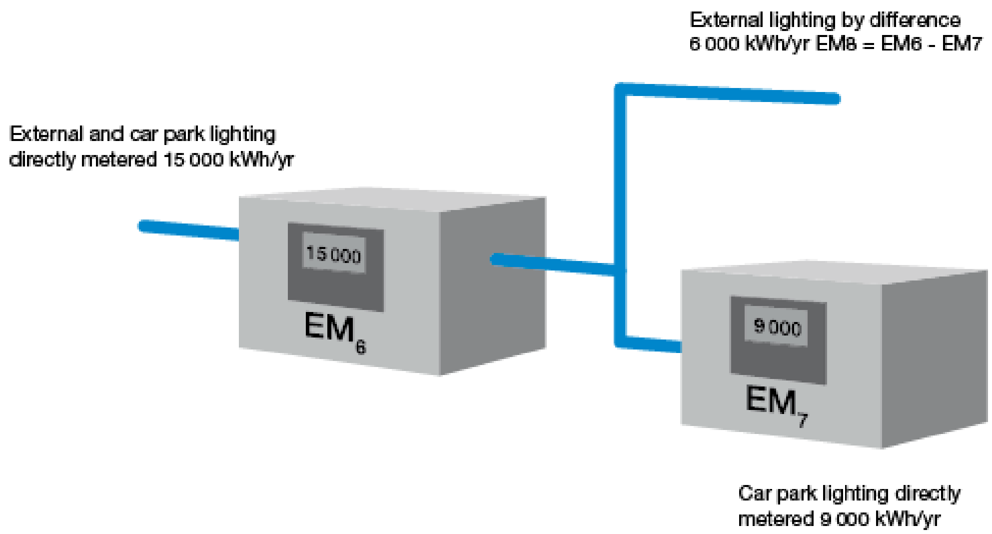
Figure 8
Indirect metering to measure consumption

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

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

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.

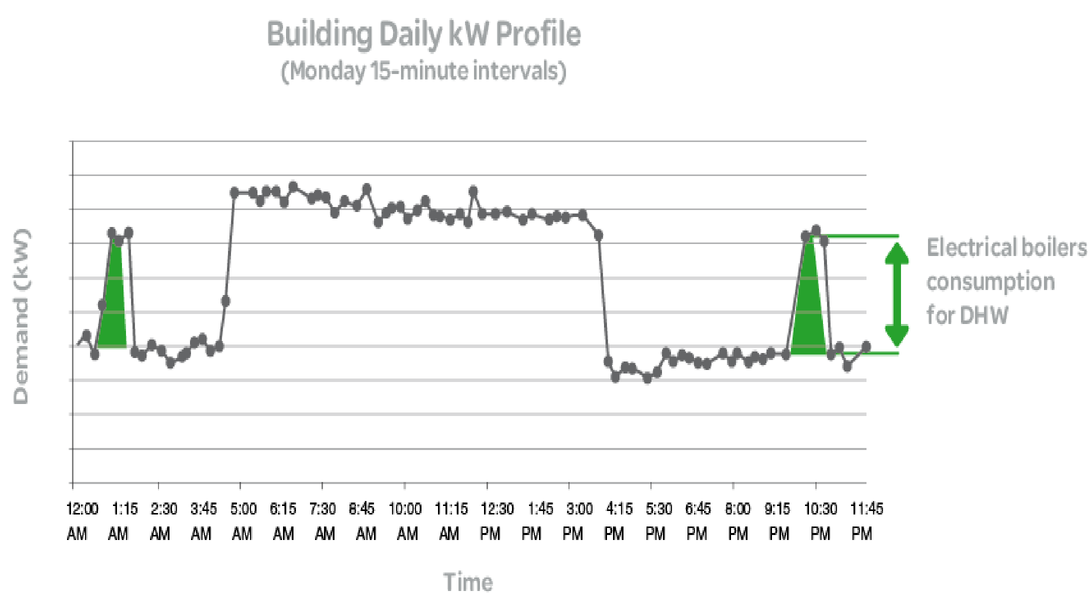
Figure 9
Two direct meters can determine 3rd measurement by difference



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 mete rs is not necessary. The chart below shows how night-time electric boiler consumption is determined by metering only the overall building load.

Figure 10
Breaking down energy use for different areas



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.

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 considerations for electric meter locations

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 be installed on each floor/tenant panelboard, so each tenant has meter access
- An electrical distribution with a busbar trunking system for easy meter access, generally due to lack of tap-off unit space.

2. Integrated or independent metering panelboard. 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).

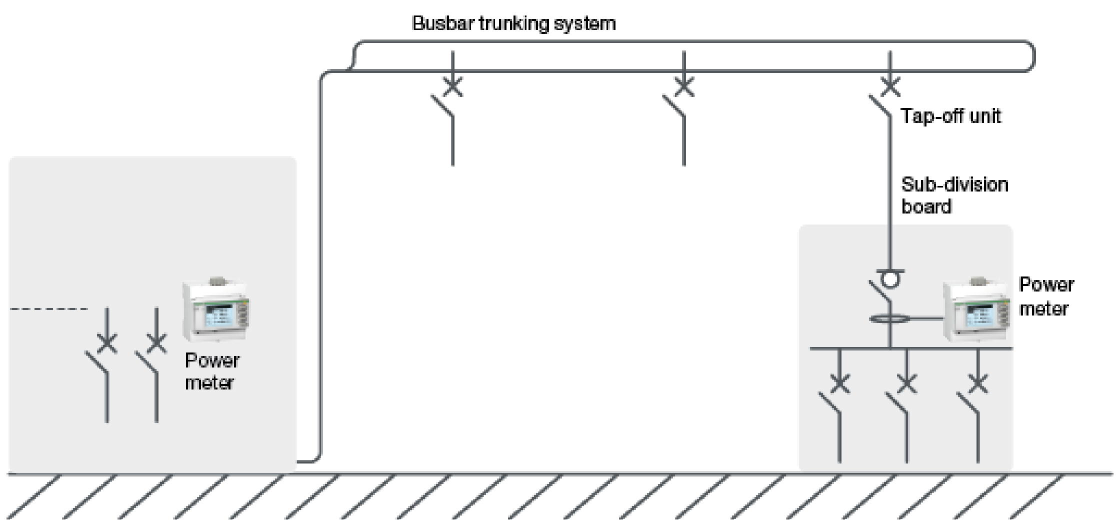


Figure 11
Special considerations for locations

Table 4

Complete the table once the metering points have been determined.

Data required to build performance metrics (Performance metric, Static data, Dynamic data) — Metering point (Recording frequency, Measurement method, Meters, Location)

	Performance metric	Static data	Dynamic data	Recording frequency	Measurement method	Meters	Location
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

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, consumption by area).

For each energy usage, we give:

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

Lighting

Data to collect according to granularity 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.

Ventilation

Data to collect according to granularity 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.

Heating and cooling

Heating and cooling is the major energy consumer in commercial buildings. It is therefore strongly advisable to use direct metering to achieve accuracy.

Refrigerant fluid – split / 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:

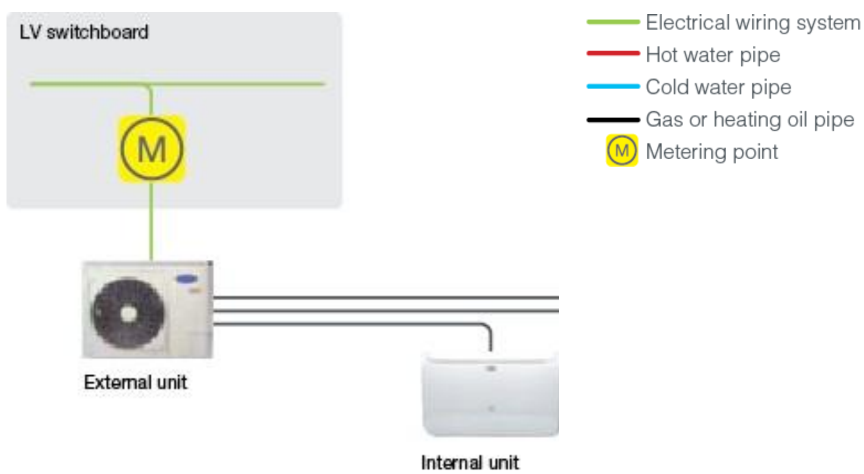
- Feeders in the main electrical switchboards for small buildings or floor/tenant panelboard for large buildings.

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.

Figure 12
Refrigerant fluid: split/multi-split system



Refrigerant fluid – VRF/VRV (Variable Refrigerant Flow/Volume)
The external unit is supplied from the LV switchboard and supplies all internal units.

Figure 13
Image of metering principle

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.

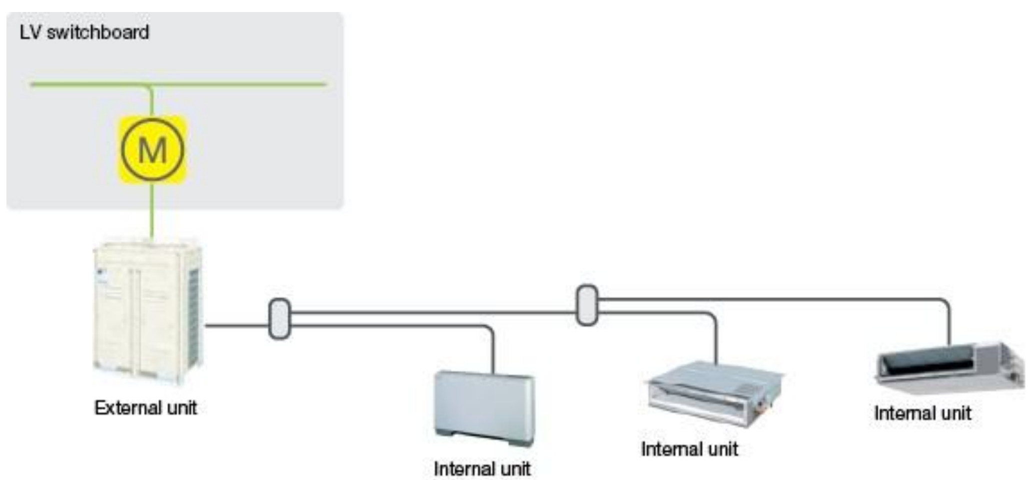


Figure 14
Electrical diagram of feeders on the main switchboard

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.

Air system – rooftop

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

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.

Figure 15
Air system electrical diagram

Air system – VAV (variable air volume)

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

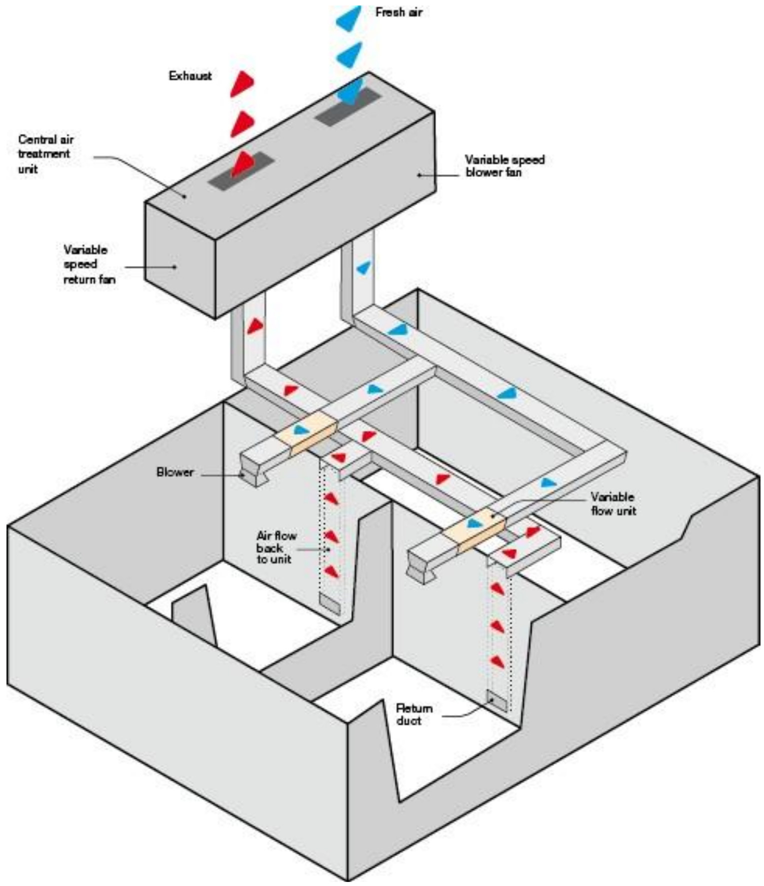


Figure 16
Variable air volume, principle diagram

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.

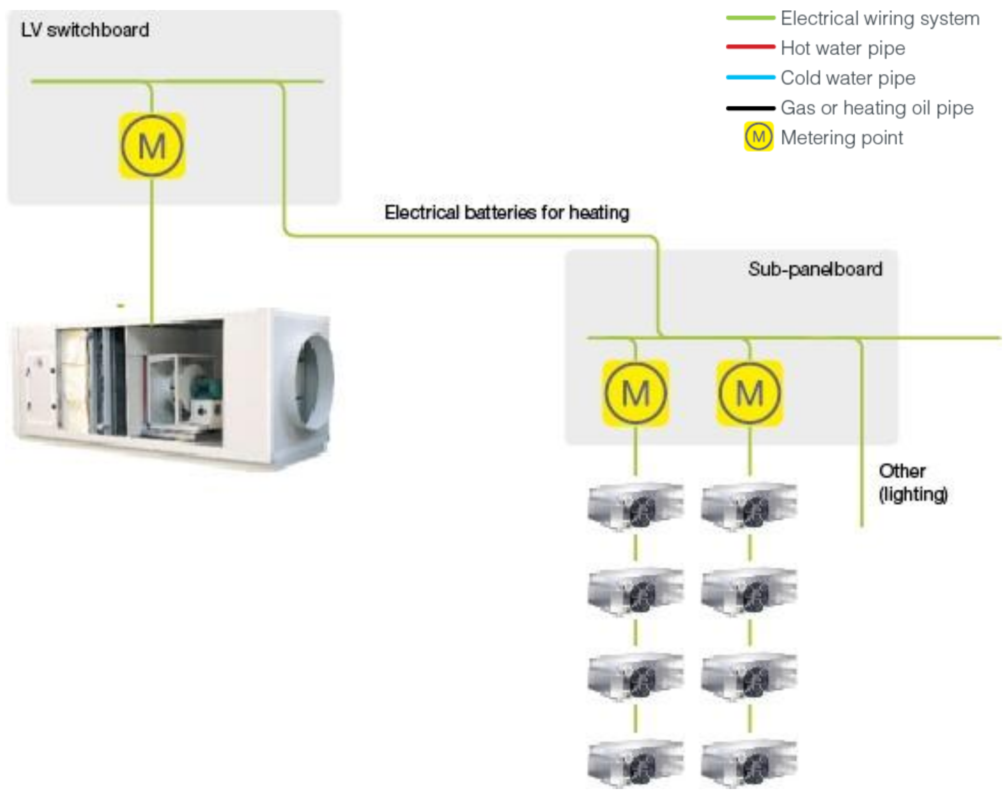


Figure 17
Variable air volume, electrical diagram

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.

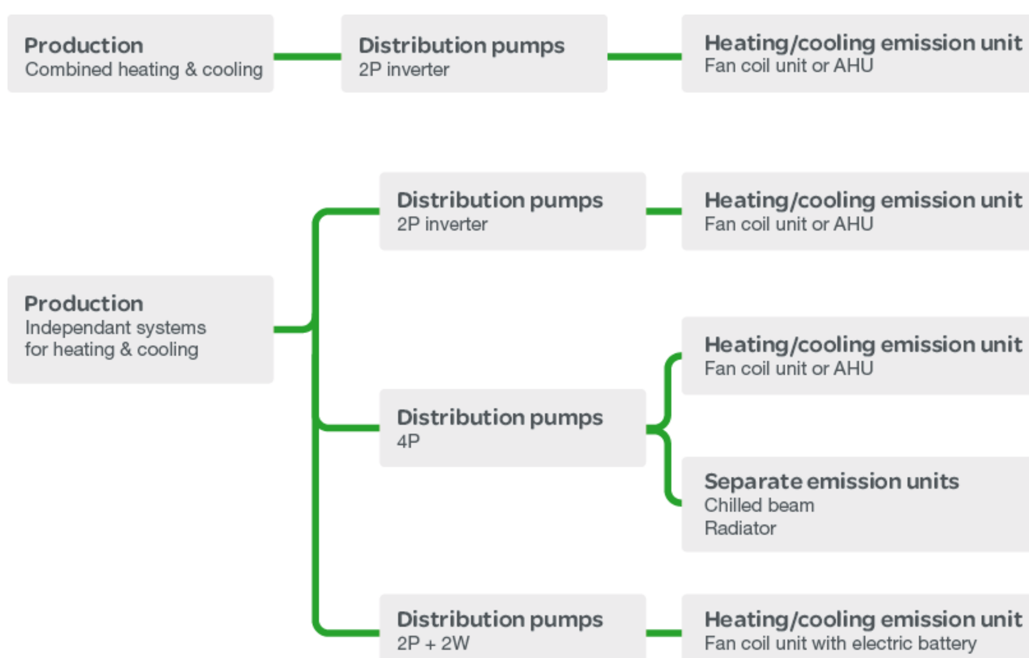


Figure 18
System components

Data to collect according to granulometry of consumption
Overall heating and cooling consumption:

- 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.

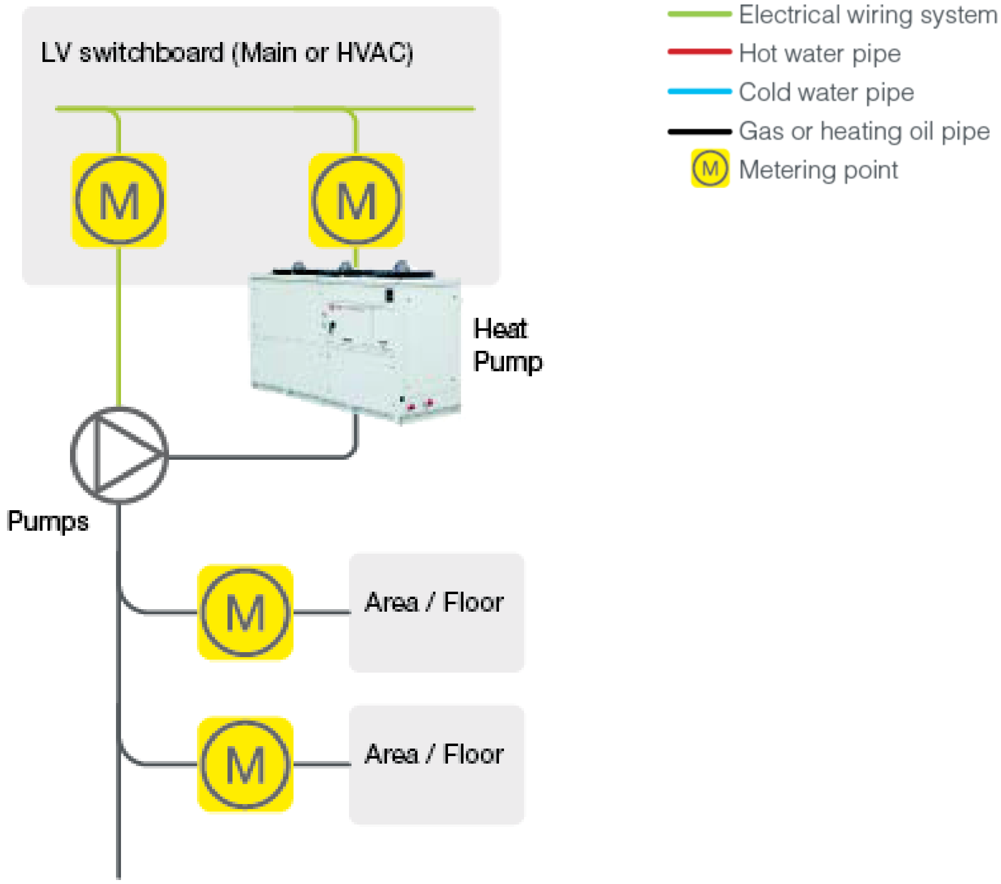


Figure 19
Water system diagram

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; should take boiler efficiency into account (% or m3/kWh).

> 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.

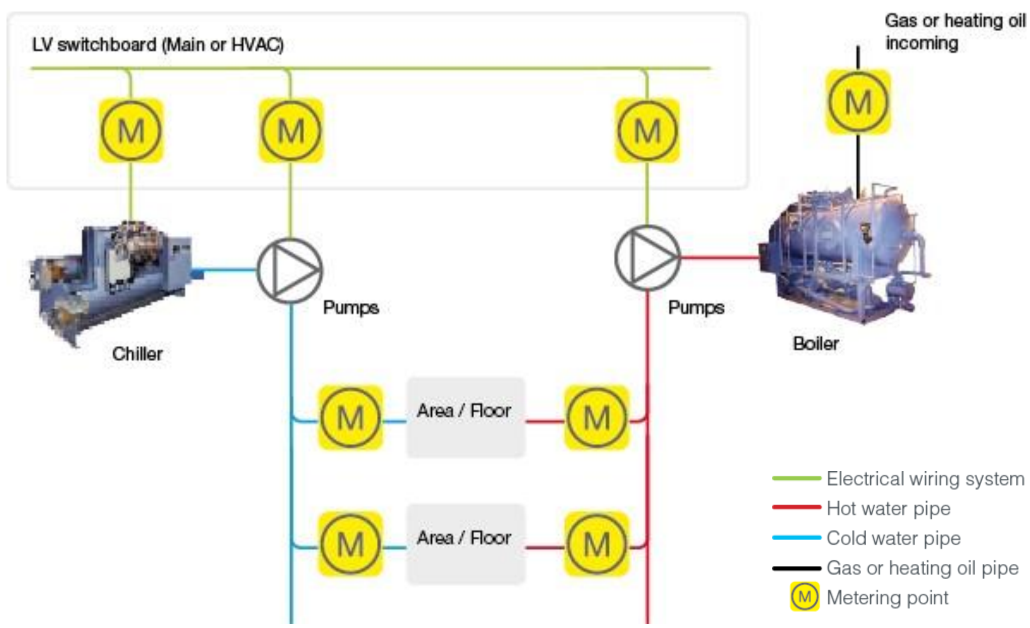


Figure 20

Boiler efficiency evolves over time. Using heat meters to measure incoming gas consumption and heating production is an effective way to monitor efficiency.

Note: Gas consumption for heating= heat meter consumption (kWh) x boiler efficiency (m3/kWh). The kWh/m3 ratio is approximately 11 for natural gas

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; should take boiler efficiency into account (% or m3/kWh).

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
- Cooling or heating mode can also be provided by the operator via data analysis system.

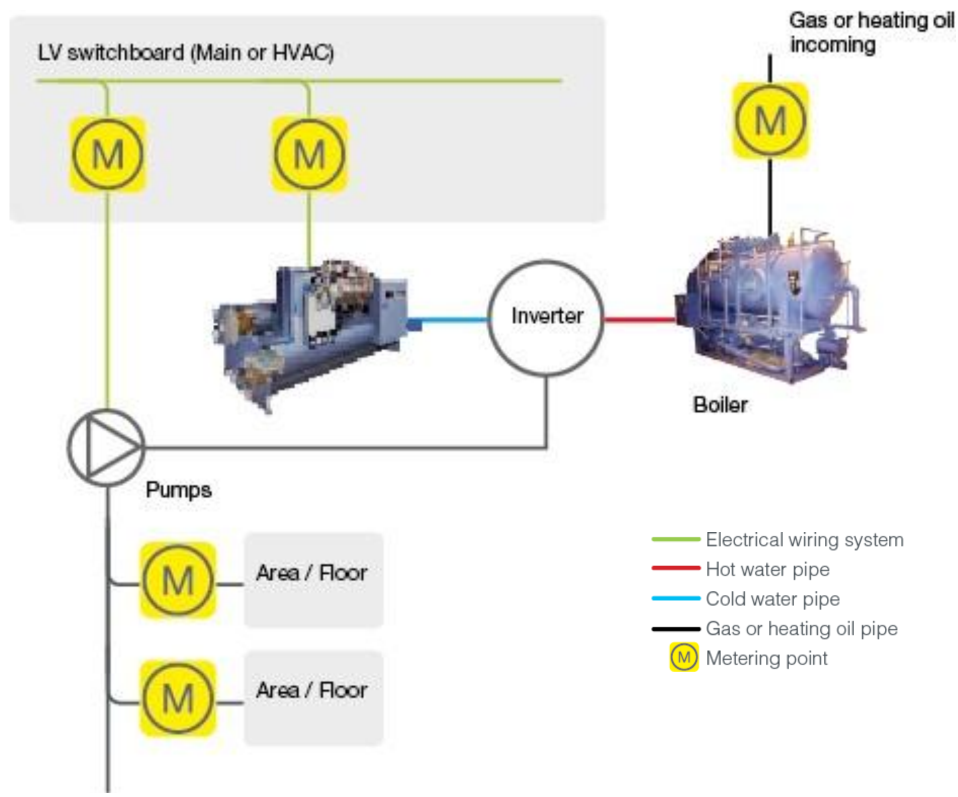


Figure 21
Boiler efficiency evolves over time. Using heat meters to measure incoming gas consumption and heating production is an effective way to monitor efficiency.

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.

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.

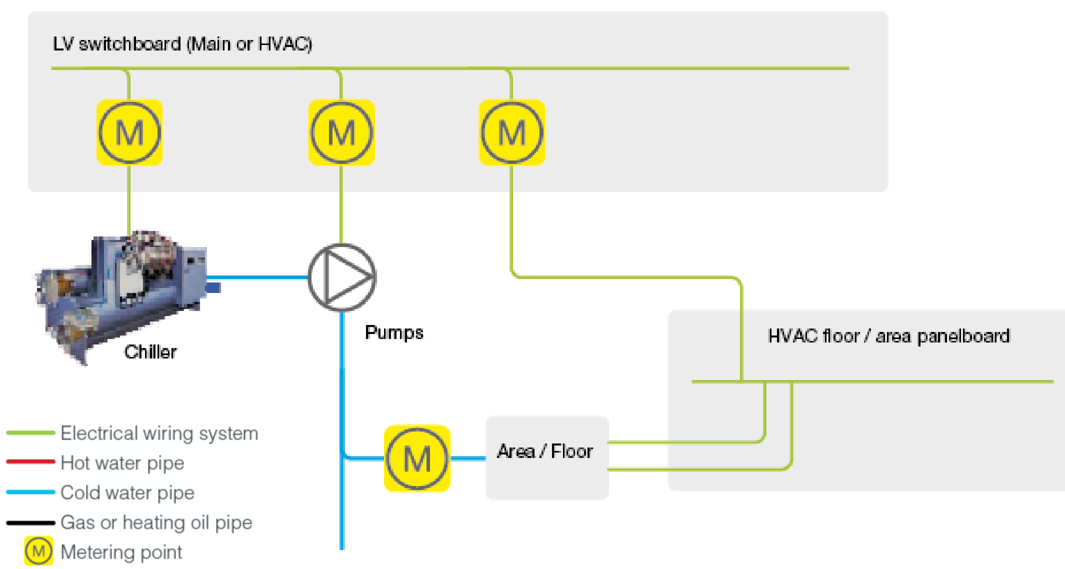
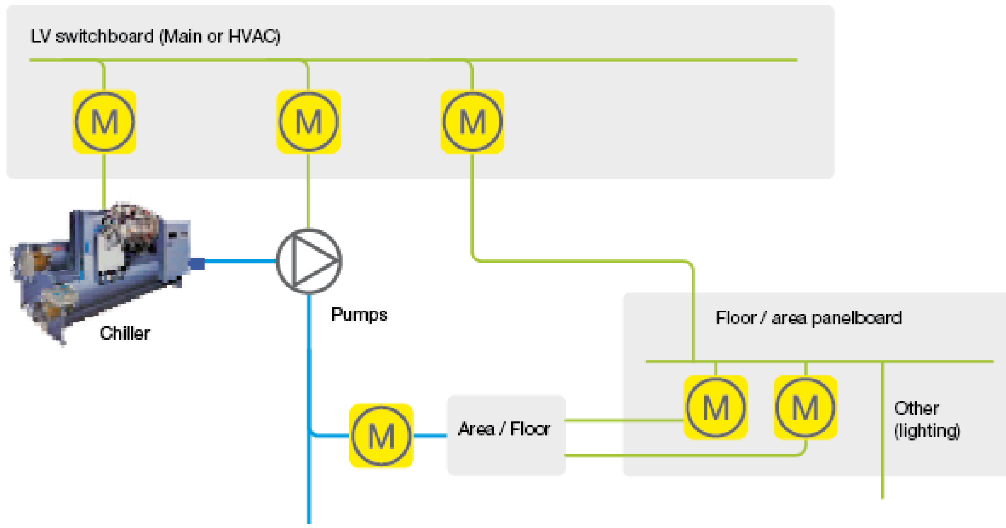


Figure 22
Independent HVAC floor panel

Figure 23
Non-independent HVAC floor panel



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

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.

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.

Method of measurement:
Direct metering: electrical meter

Metering points:
Feeders on the sub-electric switchboards

Note: Independent electric boilers include their own control; therefore an hours counter cannot be used.

Independent central gas boiler

Data to collect according to granulometry of consumption:

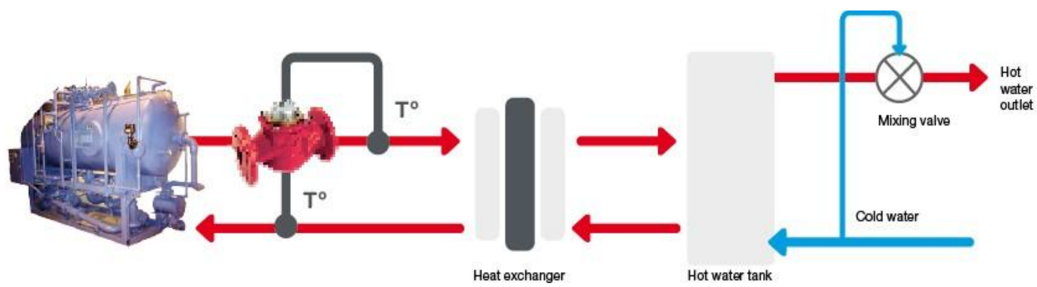
Overall consumption: gas boiler consumption and pump consumption
Area consumption: difference between the supply flow and the return flow for the dedicated area.

Method of measurement:
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.

Note: Independent central gas boiler systems may or may not use recirculation.

Figure 24
Indirect metering solution 1: heating at the primary circuit

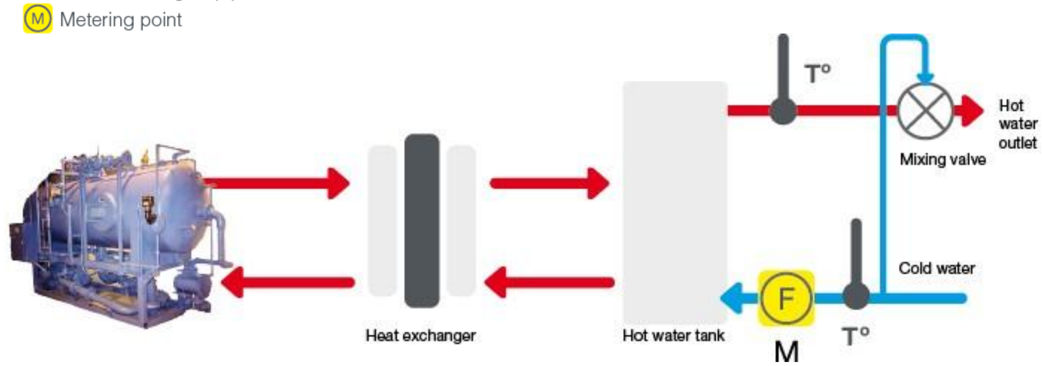


- **Solution 2** - In an existing building, hot water temperature (should be above 50°C to prevent legionella), cold water temperature, and cold water flow (leakage detection) are often already metered downstream from the hot water tank. It is then possible to calculate the DHW load with the following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

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

Electrical wiring system
Hot water pipe
Cold water pipe
Gas or heating oil pipe
Ⓜ Metering point

Figure 25
Solution 2: metering downstream from the hot water tank



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.

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.

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.

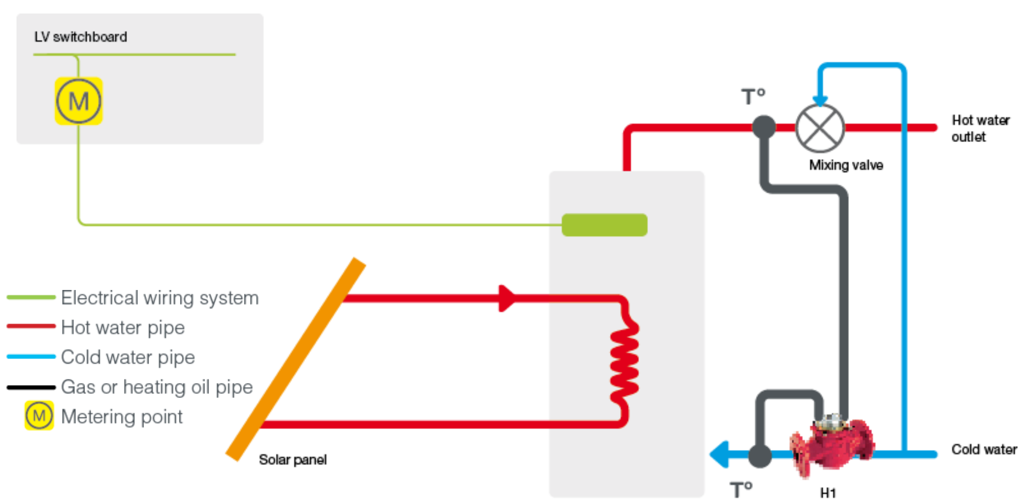


Figure 26
Solar heating with electric booster

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

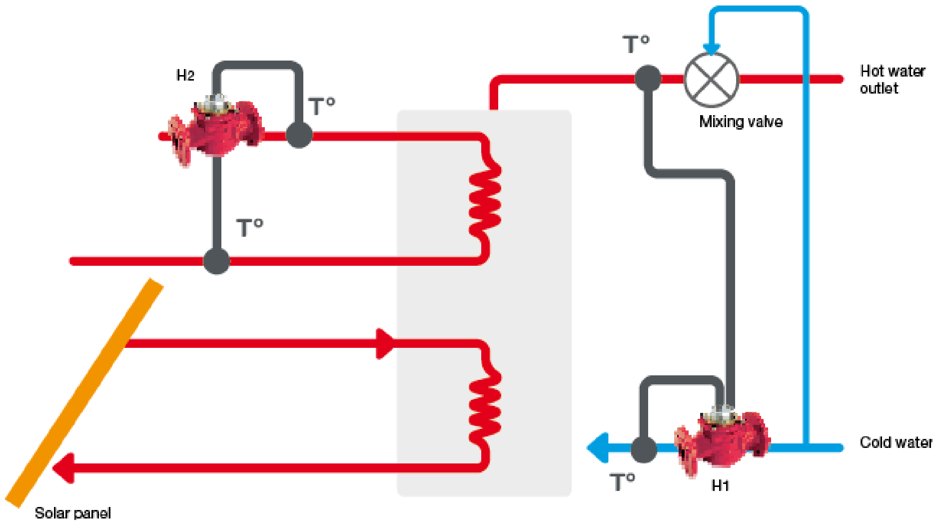


Figure 27
Solar heating with boiler booster

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)

Reusing existing main meters

Main electric meters

In some cases, existing main meters can be reused, provided they are capable of collecting data that meets the predetermined objectives.

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, or an RS485 interface with a specific communication protocol; if not, a new incoming meter should be installed.

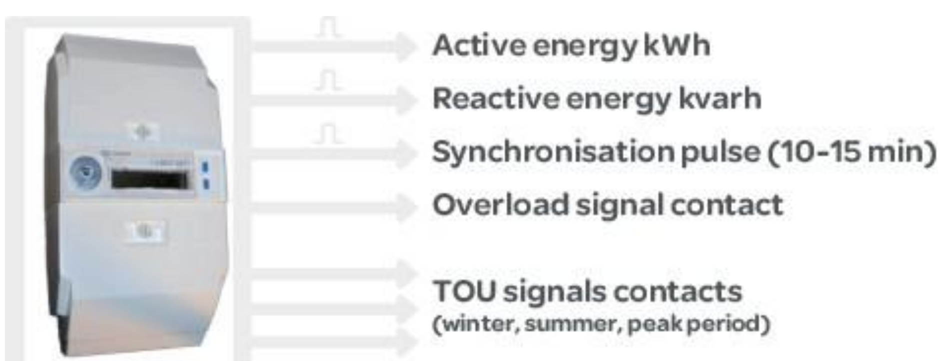


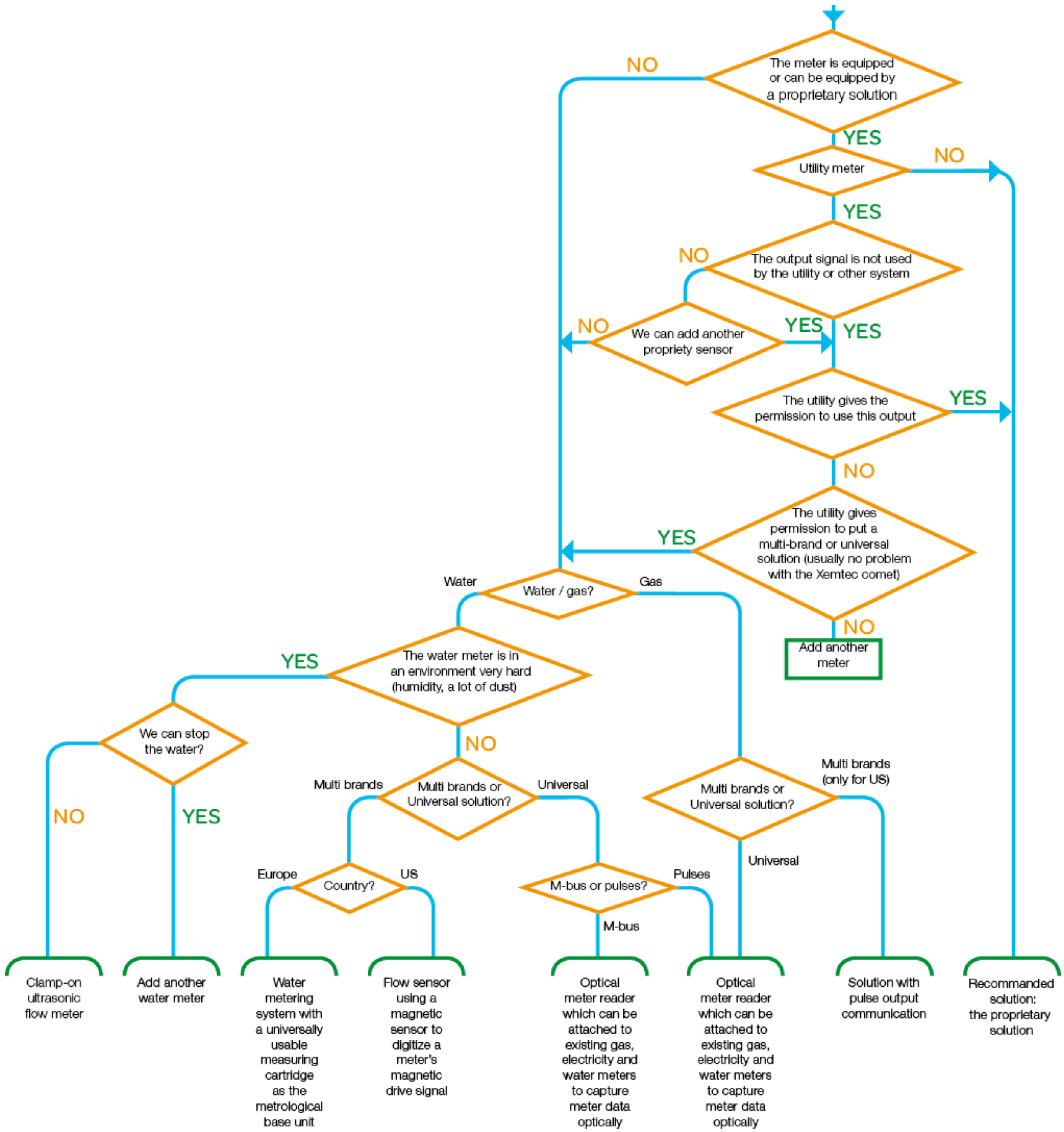
Figure 28
A variety of data may be available from the main electricity meter

Water and gas meters

Gather data from existing water and gas meters. The process for choosing the optimal solution for converting non-communicating water and gas meters into communicating meters is illustrated below.

Figure 29

Process for converting non-communicating water and gas meters into communicating meters



Selecting additional meters

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.

Criteria

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

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.

Data for electrical distribution monitoring: installation monitoring or power quality measurement
This data provides a deeper understanding of how the electrical distribution system operation, 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/event time stamping for electrical parameters
- Harmonics monitoring.

If the installation requires data for predictive maintenance (# of operations, level of wear), circuit-breakers with an appropriate trip unit are a good solution if energy metering features meet requirements.

Requirements for specific applications (i.e. sub billing, 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.

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 (dedicated product or PLC), which converts pulses into energy data and stores the data in local data logs. Recording frequency must also be accounted for (see 5.1.1), as the number of pulses/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.

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 high, especially for existing buildings. 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.

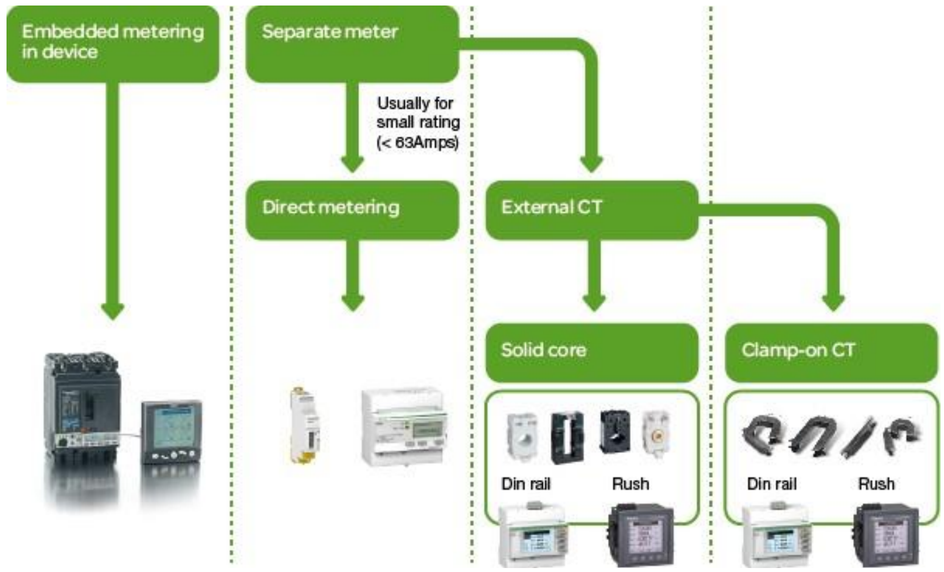


Figure 30
The different types of meter installation

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.

Figure 31
Some examples of metering devices

Direct measurement or external CTs
When a separate meter is used, it can be equipped with internal CTs that facilitate installation on the switchboard; 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.

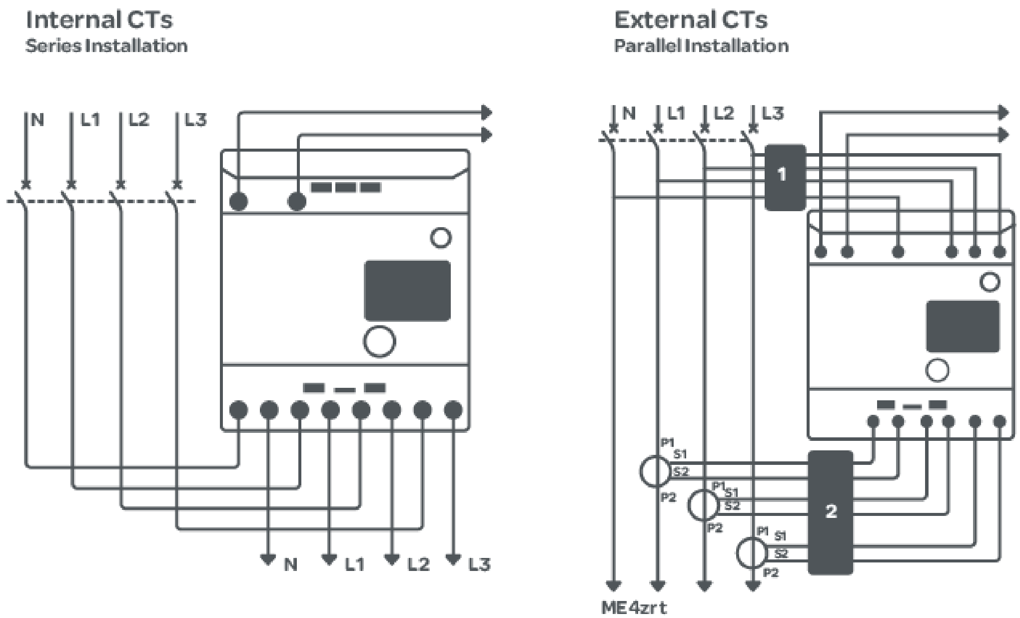


Figure 32
Internal and external CTs

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 can cost up to five times more than solid-core CTs.

(A)

Figure 33
Clamp-on (A), and solid-core (B) current transformers

(B)

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.

Criteria

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.

Needs

The category of the metering device generally depends 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
- Determination of number of operating hours of a machine or motor
- Energy consumption monitoring for:
    - Energy usage analysis
    - Building management optimisation.

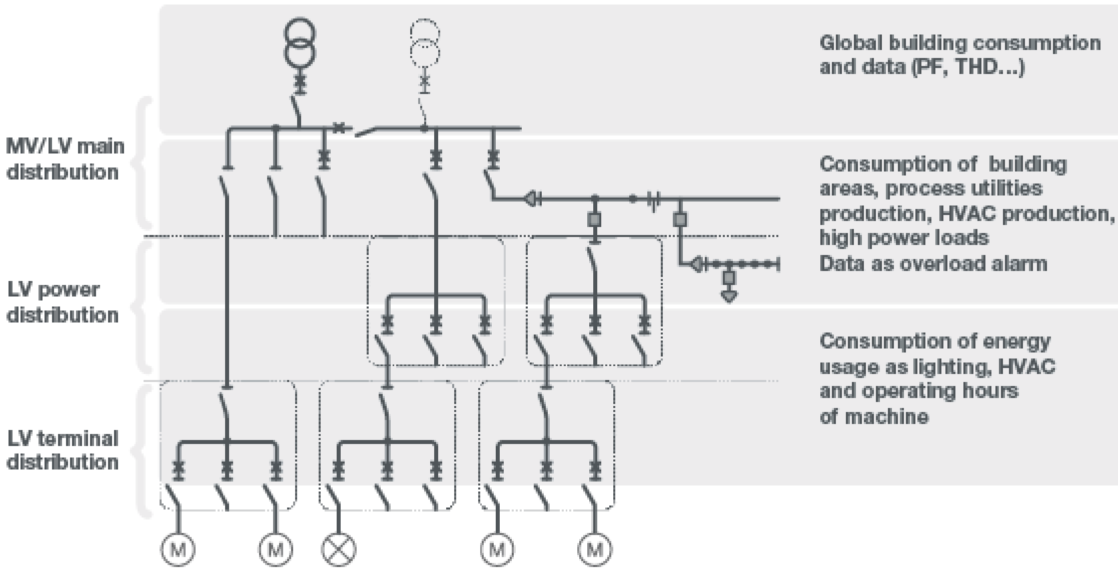


Figure 34
Metering devices should allow for a variety of measurements

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 stores, 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
In this case, “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 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.

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.

Sample case study: A 5,000m² mid-range chain hotel with 200 guest rooms

Objectives

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

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

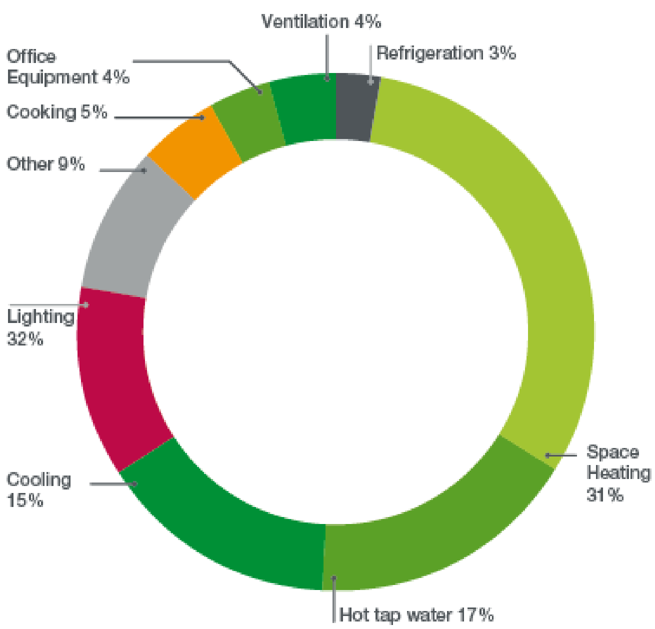


Figure 35
Determining performance metrics

Metering points

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

Table 5

Building performance metrics

Necessary data to build performance metrics

	Performance metric	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 consumption 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 pump consumption (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 pump consumption (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 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.

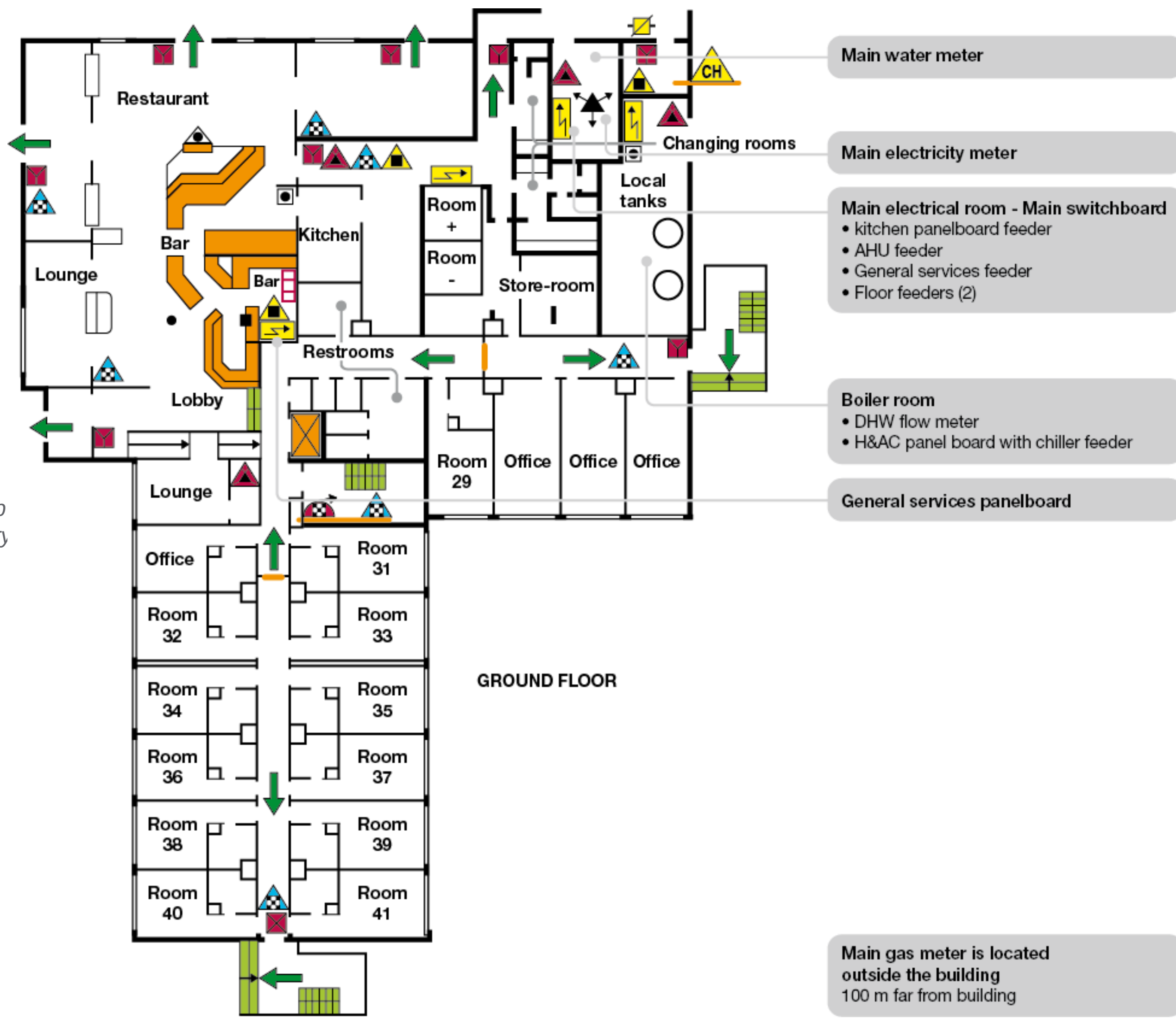


Figure 36
Floor plan to help identify necessary metering points

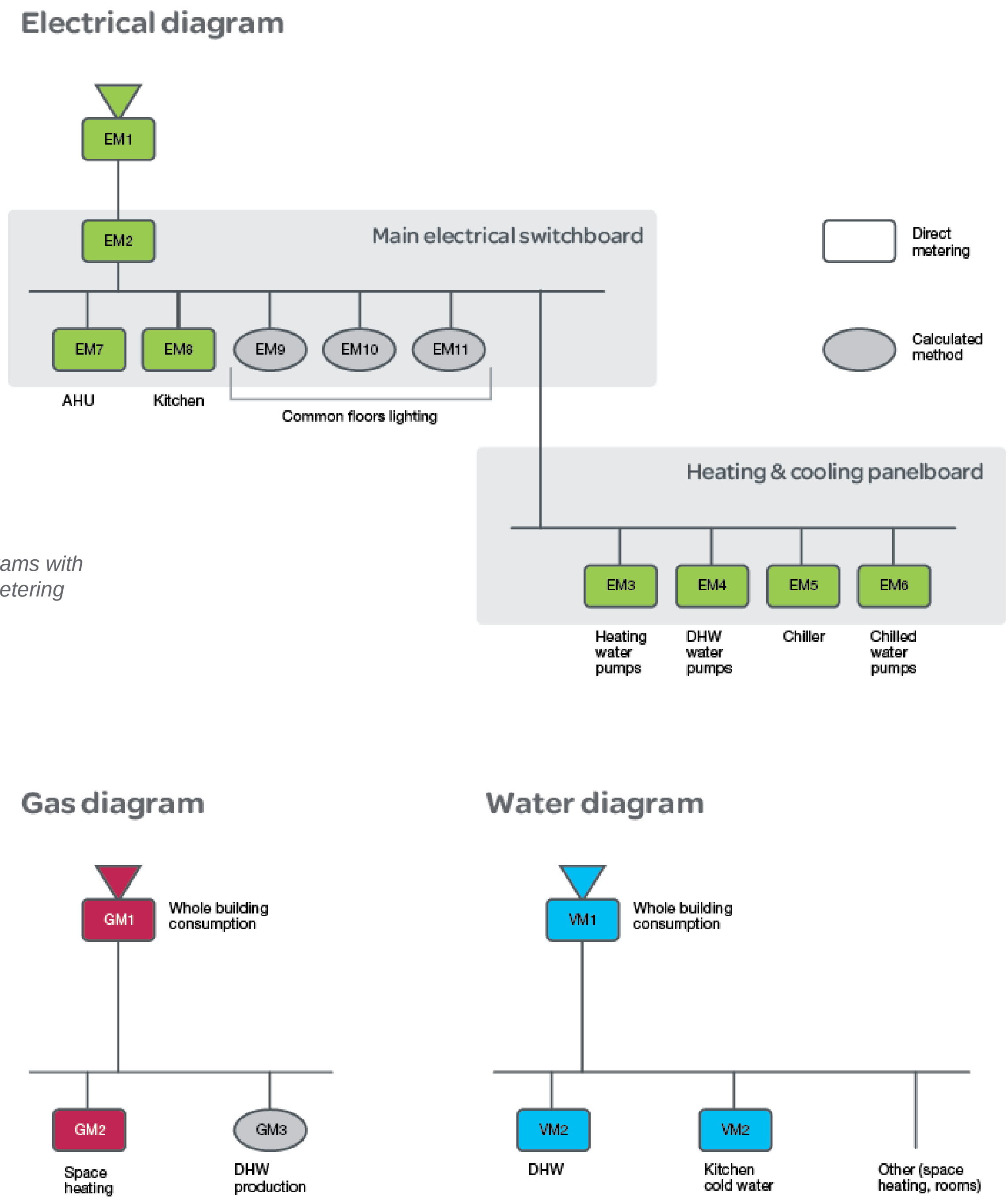


Figure 37
Metering diagrams with the different metering points.

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).

Selecting additional meters

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

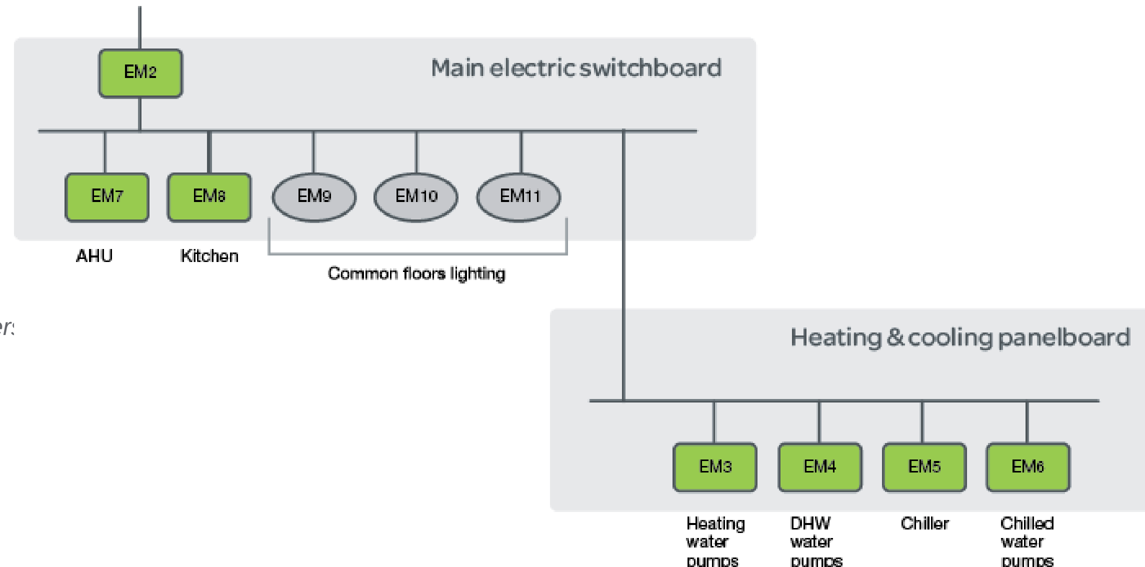


Figure 38
Selecting the right features for new meters

Table 6

Examples of meters and their characteristics

Selected meter			EM	Rating	Main characteristics
		PM5110 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
		PM3250 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
		iEM3110 with solid core	EM3, EM4, EM6	< 63 amps	Only kWh consumptions

Table 7

Metering best practices summary table (part 1)

Performance metric	Static data	Dynamic data	Recording frequency	Measurement method	Meter	Location
	Data required to build the performance metrics		*Metering points*			
Whole building EUI (kWh/m² and kWh/occupancy level)	Gross floor area (m^2) kWh/m^3 ratio for gas	Building electrical consumption (kWh)	yearly, monthly	Direct metering	Electrical meter - main switchboard incoming (EM2)	Main electrical room
		Building gas consumption (m^3)	yearly, monthly	Direct metering	Main gas meter (GM1)	Outside building
		Occupancy level	yearly, monthly	N/A	Manual reading from Hotel management system	
Whole building electricity EUI kWh/m² and kWh/occupancy level	Gross floor area (m^2)	Building electrical consumption (kWh)	yearly, monthly, weekly, daily	Direct metering	Electrical meter - main switchboard incoming (EM2)	Main electrical room
		Occupancy level	yearly, monthly	N/A	Manual reading from Hotel management system	
Whole building gas EUI m^3/m^2/HDD	Gross floor area (m^2)	Building gas consumption (m^3)	yearly, monthly, weekly, daily	Direct metering	Main gas meter (GM1)	Outside building
		Outdoor temperature (for HDD)	daily	Direct metering	Temperature sensor PT100 (TM1)	Outside building
Whole building water use intensity m^3/occupancy level		Water consumption (m^3)	yearly, monthly, weekly, daily	Direct metering	Main Water meter (WM1)	Building entrance
		Occupancy level	yearly, monthly	N/A	Manual reading from Hotel management system	
Whole building electrical consumption breakdown per TOU		Building electrical consumption (kWh)	yearly, monthly, weekly, daily	N/A	Electrical meter - main switchboard incoming (EM2)	Main electrical room
		TOU signals	weekly, daily	Direct metering	Main electricity meter (EM1)	Main electrical room meter

Table 7

Metering best practices summary table (part 2)

	Data required to build the performance metrics		Metering points			
Performance metric	**Static data**	**Dynamic data**	**Recording frequency**	**Measurement method**	**Meter**	**Location**
Whole building electrical power demand	Gross floor area (m^2)	Main electric power (kW)	yearly, monthly, weekly, daily	Direct metering	Electrical meter - main switchboard incoming (EM2)	Main electrical room
Whole building reactive energy consumption (kvarh)		Electrical reactive energy (kvarh)	yearly, monthly, weekly, daily	Direct metering	Electrical meter - main switchboard incoming (EM2)	Main electrical room
Whole building space heating EUI kWh/m²/HDD	Gross floor area (m^2)	Gas consumption for space heating boiler	yearly, monthly, weekly, daily	Direct metering	Gas sub-meter (GM2)	Boiler room
		Water pump consumption (kWh)	weekly, daily	Direct metering	Electrical meter (EM3)- heating water pumps feeder	Boiler room
		Outdoor temperature (for HDD)	weekly, daily	Direct metering	Temperature sensor PT100 (TM1)	Outside building
Whole building DHW EUI kWh/m² and kWh/occupancy level	Gross floor area (m^2) kWh/m^3 ratio for gas	Gas consumption for DHW boiler	yearly, monthly, weekly, daily	By difference GM1-GM2	N/A	N/A
		DHW pump consumption (kWh)	weekly, daily	Direct metering	Electrical meter (EM4) - DHW pumps feeder	Boiler room
Whole building DHW volume intensity m^3/m² and m^3/occupancy level	Gross floor area (m^2)	Cold water volume entering the DHW system (m^3)	yearly, monthly, weekly, daily	Direct metering	Flow meter (WM2) at entrance of the hot water tank	Boiler room
		Occupancy level	yearly, monthly, weekly, daily	N/A	Manual reading from Hotel management system	

Table 7

Metering best practices summary table (part 3)

Performance metric	Static data	Dynamic data	Recording frequency	Measurement method	Meter	Location
Total cooling EUI kWh/m^2/HDD	Gross floor area (m^2)	Chiller consumption (kWh)	yearly, monthly, weekly, daily	Direct metering	Electrical meter (EM5) - Chiller feeder	Boiler room
		Water pump consumption (kWh)	yearly, monthly, weekly, daily	Direct metering	Electrical meter (EM6) - Chilled water pumps feeder	Boiler room
		Outddor temperature (for HDD)	yearly, monthly, weekly, daily	Direct metering	Temperature sensor PT100 (TM1)	Outside building
Total ventilation EUI kWh/m^2	Gross floor area (m^2)	AHU electrical consumption	yearly, monthly, weekly, daily	Direct metering	Electrical meter (EM7) - AHU feeder	Main electrical room
Kitchen electrical consumption (kWh)		Kitchen electrical consumption	yearly, monthly, weekly, daily	Direct metering	Manual reading from hotel management system	
Kitchen water consumption (m^3)		Kitchen water consumption (m^3)	yearly, monthly, weekly, daily	Direct metering	Water sub-meter (WM3)	
Lighting common areas EUI	Gross floor area (m^2)	Lighting consumption of common areas(kWh)	yearly, monthly, weekly, daily	By data analysis - from general service consumption	Electrical meter (EM8) - General services panelboard feeder	Main electrical room

Data required to build the performance metrics: Performance metric, Static data, Dynamic data. Metering points: Recording frequency, Measurement method, Meter, Location.

Conclusion

Robust management, monitoring and control of energy usage can deliver up to 30% energy savings

Designing metering systems in brief

- Set objectives to identify user needs and determine the scope of future energy monitoring systems. Users of the system should provide input on the main features that should be included.
- Determine performance metrics and the data to be measured that will link building activity and energy consumption.
- Determine the metering points that will allow operators to monitor and control the building according to their objectives, and to ensure gathered data enables the desired analysis.
- Select meters based on your objectives. If main meters are able to read energy data, reuse may be possible, otherwise new incoming meters should be installed. Select additional meters as per metering points requirements and building operation requirements and objectives.

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