OFFICE OF ENVIRONMENT & HERITAGE

Energy and water metering and monitoring guide for aquatic centres

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Acronyms and abbreviations

BMS	building management system
CDD	cooling degree days
COP	coefficient of performance
EnPI	energy performance indicator
ESCs	energy savings certificates
ESS	Energy Savings Scheme
GJ	Gigajoule
HDD	heating degree days
HVAC	heating, ventilation and air conditioning
KPI	key performance indicator
kWh	kilowatt hours
M&V	measurement and verification
OEH	Office of Environment and Heritage
SCADA	supervisory control and data acquisition
VSD	variable speed drive
AHU	Air Handling Unit
DHW	Domestic Hot Water

About this guide

We cannot manage what we do not measure.

This guide was developed by the Office of Environment and Heritage (OEH) and accompanies other OEH guides including the Energy efficient water heating technology guide for aquatic centres (co-located with this guide) and the Electricity metering and monitoring guide (for businesses).

It provides expert advice on measuring and monitoring water, electricity and gas usage for aquatic centres. It will help you identify the required data, choose a suitable metering arrangement, plan a metering and monitoring program, assign responsibilities to ensure action is taken, and identify opportunities to reduce energy and water costs.

Developing a metering and monitoring plan for your aquatic centre

There are four main steps to developing a metering and monitoring plan as illustrated in Figure 1.

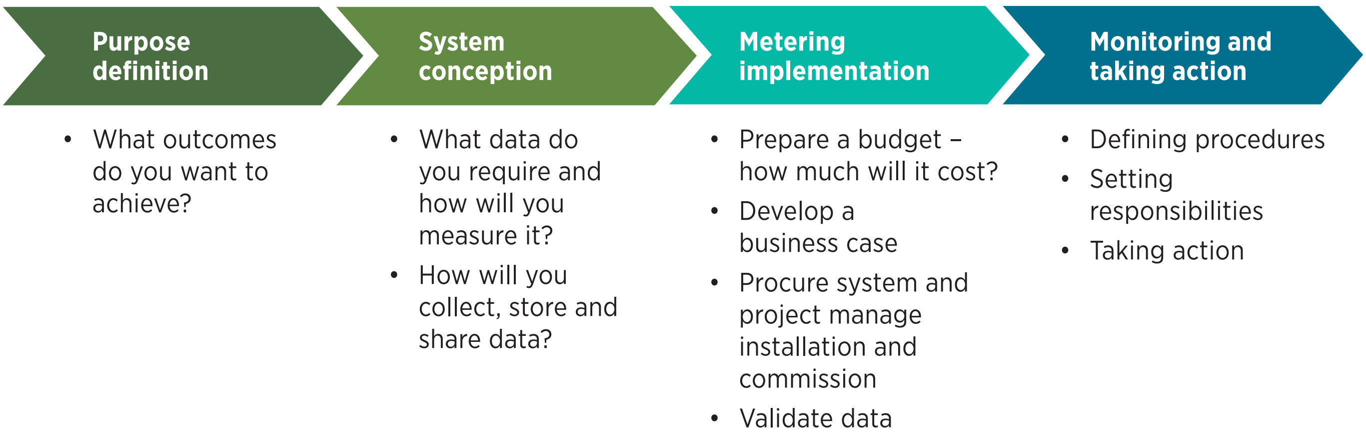


Figure 1 Developing a metering and monitoring program

Step 1 – Purpose definition

Why do you want to meter and monitor?

Energy and water are the two largest resources consumed in an aquatic centre, accounting for up to 90% of operating costs. They can also be the greatest source of waste if not correctly monitored and managed. Metering and monitoring the water and energy consumption of an aquatic centre is essential and can benefit several different areas of the organisation, including:

- **Operations:** benchmark and optimise the operation of equipment, detect changes in equipment performance and determine waste inefficiencies
- **Finance:** energy cost allocation, energy cost reduction, collect evidence to support a business case
- **Management:** reporting on performance and sustainability targets.

A key rationale for metering and monitoring is to enable aquatic centres to adopt water and energy performance indicators for:

- energy consumption (gas and electricity) at the site level
- water consumption at the site level
- efficiency of the main water heating systems.

Appendix 1 provides a thorough list of water and energy performance indicators and data to be collected.

Other reasons for implementing a metering and monitoring system include:

1. Monitor energy consumption at the site level to measure and verify savings from an energy efficiency upgrade.
2. Monitor the coefficient of performance (COP) of heat pumps and efficiency of other plant equipment such as boilers, and automatically start the most energy efficient ones first.
3. Implement peak demand management (automatically turn off electrical equipment when electricity demand reaches a specific threshold to reduce peak demand charges).

It is important to take of note of the factors that impact on water and energy use such as patronage levels, time of year, internal and external temperatures.

North Sydney Olympic Pool developed an extensive sub-metering plan which was implemented in 2017 to identify and quantify the energy flows throughout the site. The metering identified a number of energy saving opportunities including optimisation of the different heating systems – cogeneration system, heat pumps, and solar system – coupled with new BMS interfaces.

For full case study see Office of Environment & Heritage's Energy efficient water heating technology guide for aquatic centres (co-located with this guide).

Photo: North Sydney Council

Step 2 – System conception

What data do you require and how will you measure it?

Based on the reasons identified in Step 1, list all the data that you need to measure.

Physical values such as temperature, flow rate, water or energy consumption should be directly measured by dedicated meters (such as a temperature sensor, flow meter, or gas meter).

There are some situations where data can be determined by indirect measurement, using engineering calculations and assumptions to calculate a specific value. For example:

- when a motor is connected to a VSD, its power consumption can be calculated based on electrical current recorded by the VSD, removing the need for an energy meter
- flow rate can be estimated based on the pump characteristics and motor speed, removing the need for a flowmeter.

While indirect measurement is not as accurate as actual metering, it is cheaper and replicable, measurements will be similar under the same conditions and observing consumption trends provides very useful information. It can be a first step in justifying the purchase of meters, and help build the business case for implementing metering and monitoring systems.

For the measurement of energy and water consumption at the site level, utility meters should be used where possible. Site level data can be obtained in three ways:

1. From the energy retailer or water retailer via an online database.
2. Directly from the meter via an automated on-site data collection system. Note that this option may require the replacement of the meter.
3. Installing a sub-meter (or a private meter) downstream of the utility meter. This also helps for bill validation.

Appendix 2 and 3 show the typical metering arrangement of water, electricity, and gas at the site level, and for the most common water heating systems.

How will you collect, store, and use data?

To monitor a system, all relevant data should be used. This can be collected manually or automatically. For example:

- **manual data collection:** an operator records the reading from the power meter at a suitably convenient interval, e.g. every morning, into a spreadsheet and plots the chart to detect potential drift in energy performance
- **automatic data collection:** a power meter or data logger automatically sends power readings to a data collection system (such as a BMS) which automatically plots the daily electricity consumption and usually sends an alert if the daily consumption reaches a specific threshold.

Automation reduces operating costs and human errors but increases system complexity and the initial investment. To ensure reliability and consistency and minimise manual handling, it is recommended to automate all data collection and reporting tools wherever possible. The following schematic shows the overall structure of an automatic data collection system.

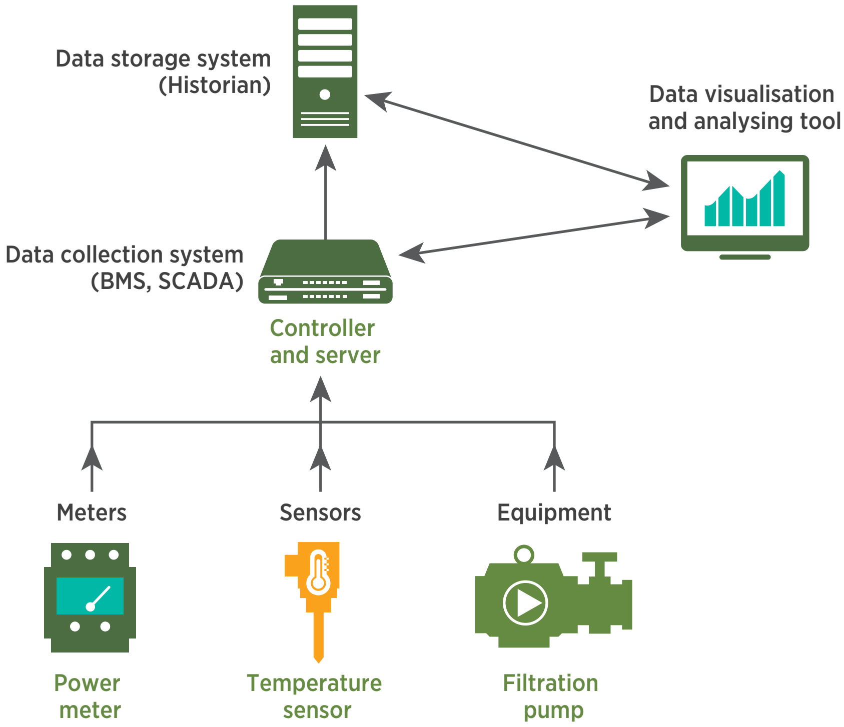


Figure 2 High-level overview of a BMS or SCADA system structure

Figure 3 Screenshot of a typical BMS system

The following table highlights the main advantages and disadvantages of a manual and automated data collection system.

Table 1 Main differences between manual and automated data collection systems

	Manual system	Automatic system (BMS/SCADA)
Cost	✔ Cheap	✘ Installation fee and on-going fees
Ease of use and modification	✔ Easy	✘ Complicated
Consistency	✘ Not consistent (data may be collected at different time intervals)	✔ Can customise time interval for each meter
Human error risk	✘ High (misread of meter readings or deletion of data)	✔ Low
Control capabilities on pool equipment	✘ None	✔ Yes
Scalability	✘ None	✔ Yes (more meters can be added, and external databases can be integrated, such as weather data or utility data)
Automatic alarming capabilities	✘ None	✔ Yes
Other comment	✘ Manual systems require labour which can be expensive	✔ Other features in automated systems can include: • Automatic reporting capabilities • Data access control • Data backup system • Alarm history • Remote data access

Note: All data should be stored for at least two years.

Junee Aquatic & Recreation Centre in NSW Riverina installed gas, electricity and water meters connected to a new building management system (BMS) to monitor energy and water consumption and permit fine tuning resulting in a 13% reduction in energy use, saving around $25,000 per year.

For full case study see the Energy efficient water heating technology guide for aquatic centres (co-located with this guide).

Photo: Junee Shire Council

Step 3 – Metering implementation

Prepare a budget → Develop a business case → Install and commission → Validate

Prepare a budget

Cost considerations for a metering and monitoring system include:

- project management
- equipment procurement and installation
- maintenance
- validation during the life of the meters and sensors
- data collection and storage
- ongoing data analysis and reporting
- staff training.

See **Appendix 4** for indicative costs for metering and monitoring.

Develop a business case

Depending on the complexity of the metering and monitoring system and the funding approval processes, you may need to develop a business case. At a minimum, your business case should include the following:

- project objectives (Step 1)
- detailed description (Step 2)
- costs (prepare a budget)
- benefits – a metering system does not generate savings, however, studies[1] suggest a minimum of 5% energy savings can be attributed directly to actions that result from access and use of better data.

Procure system and project manage installation and commissioning

The installation and commissioning of meters will require qualified people with expertise in the following:

- plumbing – for any work affecting water or gas pipework
- electrical – for power supply, and power meter installation
- automation – if meters are connected to a data collection system (BMS or SCADA)
- engineering – for the control of equipment or the design of the metering arrangement.

Figure 4 Plumber installing manual read water meters. (Shutterstock)

1 Office of Energy Efficiency of Natural Resources Canada, Achieving Improved Energy Efficiency, available at www.nrcan.gc.ca/energy/publications/efficiency/industrial/emis/6769

Validate data

Once installed and commissioned, readings from meters should be checked and validated to ensure accuracy and correct inter-phasing with management system. For example, a pulse water meter can provide accurate readings, however, the multiplier applied by the BMS to convert pulses to a water volume will require adjusting to ensure that it is correct.

Some service providers can provide a 'one-stop-shop' service, i.e. select, specify, supply, install, commission, calibrate and validate metering equipment, as well as providing a data handling system.

Figure 5 Power meter. (OEH)

Figure 6 Electrical meter. (OEH)

Figure 7 Water flowmeter. (Shutterstock)

Figure 8 Temperature sensor on water pipe. (Shutterstock)

Step 4 – Monitoring and taking action

Define procedures

Set clear procedures to:

- access raw data from the data collection system
- access records of maintenance checks on specific assets
- request an efficiency test
- change control set points and control strategies
- set new automatic alerts.

Automatic alerts are the most efficient tool to quickly and effectively inform operators about a loss in performance so that corrective actions can be undertaken. Automatic alerts can refer to the quality of service (such as pool water temperature, pool hall air temperature, pool water turnover rate, etc.), or the performance of specific equipment (such as the COP of heat pumps, daily electricity consumption of filtration pumps, etc.).

Defining these alerts is an iterative process: issues reported by customers or pool operators, or the installation of new tools can justify the implementation of a new alert to improve the quality and performance of the aquatic centre. It is important to review all alerts on a quarterly or annual basis to ensure that they are all relevant and set correctly.

Set responsibilities

To ensure the success of the metering and monitoring program, you must set responsibilities. For example:

- Who will collect the data?
- Who will analyse the data?
- Who will check and review the data, and how often?
- What are the communication channels to report and escalate changes in water or energy consumption?

The required frequency for reviewing the data depends on what the operator is looking for:

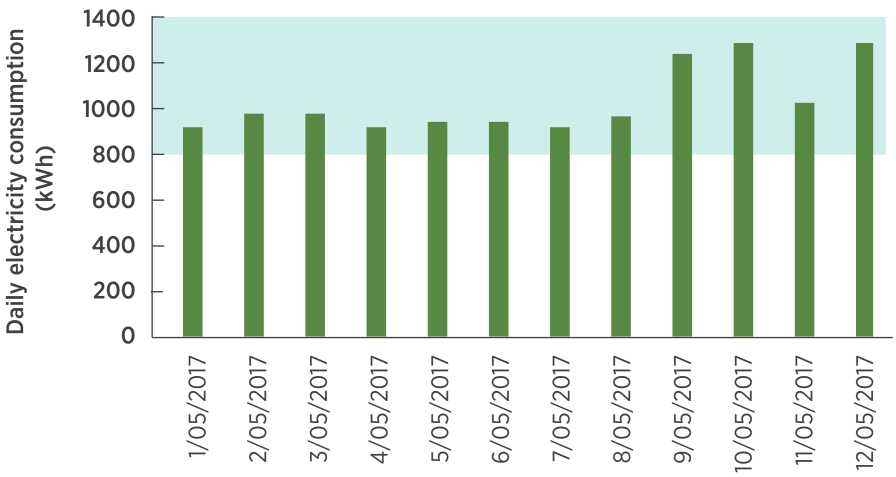
- in the case of water and energy performance indicators, **Appendix 1** gives recommended reviewing frequencies
- in the case of an operational change, energy or water consumption should be reviewed daily for a certain period to ensure that the new operating conditions are not negatively affecting the water or energy consumption of the aquatic centre.

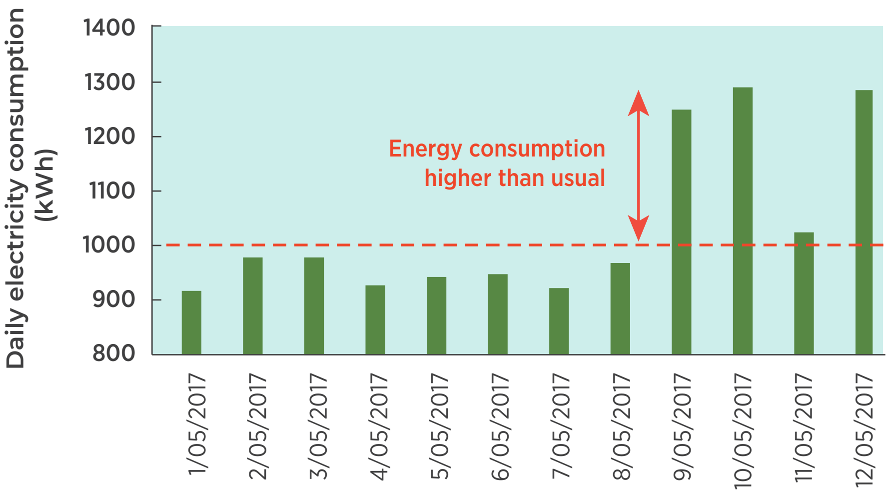
Taking action

The most important part of your measuring and monitoring program is taking action to improve efficiency and rectify issues identified during monitoring. **Figure 9** shows how data from a metering and monitoring system detected spikes in electricity usage in an aquatic centre pumping system, which were analysed by skilled staff to identify and correct the cause of the spikes.

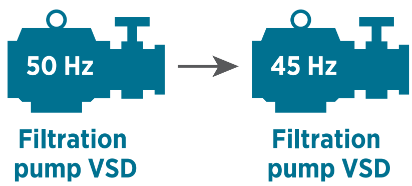
Figure 8 Accessing metering and other data recorded in aquatic centre SCADA system. (E+A Clark Photography)

	A	B	C
1	ReportDateStart	ReportDate	KW
2	1/05/2017	0:15	45.3
3	1/05/2017	0:30	49.8
4	1/05/2017	0:45	45.1
5	1/05/2017	1:00	45.1
6	1/05/2017	1:15	49.7
7	1/05/2017	1:30	46.1
8	1/05/2017	1:45	53.4





The investigation showed that during the maintenance of one of the filters, the motor speed of the filtration pumps was changed but not returned to original value. Procedural changes were put in place to ensure it was not repeated. At the end of the maintenance work, the operator had forgotten to change the motor speed back to its original value.



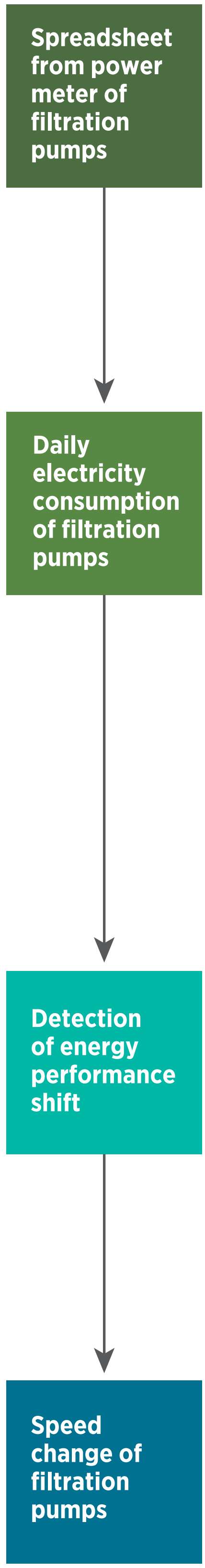


Figure 9 Detection and analysis of spikes in electricity use in filtration pumps at an aquatic centre, and resulting procedural change

What to do next?

The task of measuring and monitoring is is an ongoing process, never a one off. Think of it as a journey rather than a destination. There are always other ways to refine the quality and relevance of the data to collect and analyse. This guide is the first step on the journey to continuous improvement and efficiencies for pool operators.

Appendices

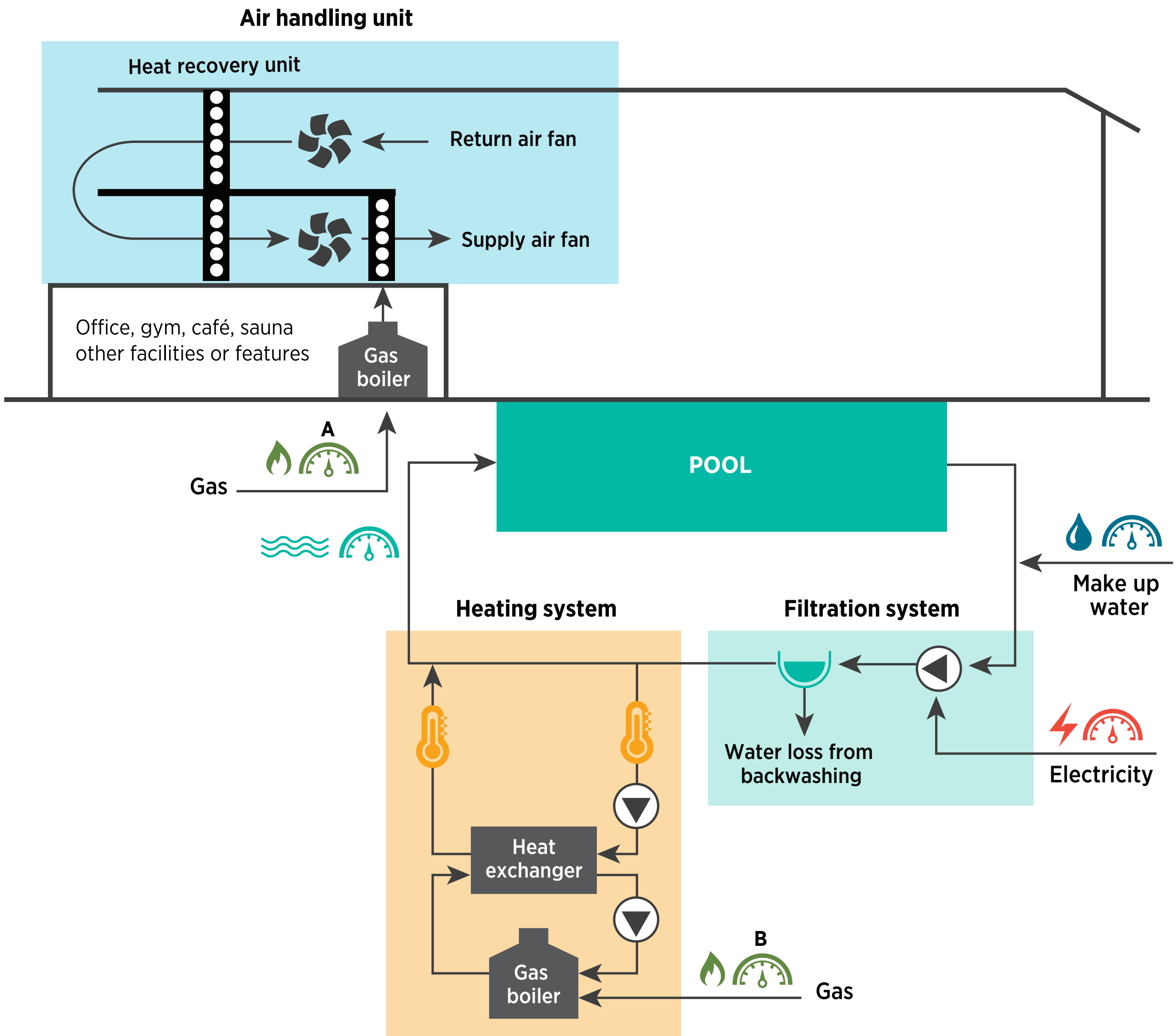
Appendix 1 – Water and energy performance indicators for aquatic centres

	Indicators	Description	Data required	Reviewing frequency and how do you use data
Site level	Gas or Electricity or Total Energy consumption of the site per HDD and CDD	The total energy consumption of an aquatic centre is highly dependent on the weather conditions. The energy consumption of gas and electricity can be correlated to the Heating Degree Days and Cooling Degree Days. This correlation can be made on a daily, weekly, or monthly basis.	• Electricity consumption data from utility meter • Gas consumption data from utility meter • Heating and Cooling Degree Days (can be calculated based on temperatures recorded by the Bureau of Meteorology temperatures or taken from dedicated service providers)	**Quarterly basis:** Review the actual energy consumption of the site compared to the energy model. **Automatic alarm:** Alert operators if the energy consumption (over a day, week, or month) is unusually higher than that predicted by the energy model.
Equipment level	Gas Boiler Efficiency (if applicable)	The efficiency of a gas boiler can reduce over time due to scaling, change of control settings, or corrosion. Measuring the efficiency over time allows the early detection of faults. It requires knowing the gas input and heat output of the boiler.	• Gas input (gas flow rate) • Thermal output (flow rate and temperatures of water going in and out of the boiler)	**Annual basis:** Review the average monthly efficiency of the water heating system. **Automatic alarm:** Alert operators if the efficiency of the system drops below an acceptable range (based on historic performance and design specifications).
Equipment level	Heat Pump Efficiency (if applicable)	The efficiency of electric heat pumps can depreciate over time due to refrigerant leaks, scaling of the heat exchanger, degradation of the compressor, or corrosion. Measuring the efficiency over time allows the early detection of faults. It requires knowing the electricity input, heat source conditions (air temperature if it is an air-to-water heat pump), and heat output of the heat pump.	• Electricity input (power meter) • Thermal output (flow rate and temperatures of water going in and out of the heat pump) • Outside air temperature (if air-to-water heat pump) or water temperature (if water-to-water heat pump)	

	Indicators	Description	Data required	Reviewing frequency and how do you use data
Equipment level	Solar System Efficiency (if applicable)	The efficiency of a thermal solar system can depreciate over time due to dust building up on the collector, leaks of the refrigerant, scaling of the heat exchanger... Measuring the efficiency over time allows the early detection of faults. It requires knowing the solar irradiation and heat output of the boiler.	• Solar irradiation available from the Bureau of Meteorology • Thermal output (flow rate and temperatures of water going in and out of the heat exchanger)	**Annual basis:** Review the average monthly efficiency of the water heating system. **Automatic alarm:** Alert operators if the efficiency of the system drops below an acceptable range (based on historic performance and design specifications).
Equipment level	Cogeneration System Efficiency (if applicable)	There are two main indicators for cogeneration systems: • Electrical efficiency • Overall efficiency (thermal + electrical) It requires knowing the gas input, electricity output and thermal output of the cogeneration system.	• Gas input (gas flow rate) • Electricity output (power meter) • Thermal output (flow rate and temperatures of water going in and out of the heat exchanger) Gas and electricity meters are usually installed as a default feature. The thermal output, however, is not always measured.	
Equipment level	Energy Performance of other pool water heating system	If you are using another type of water heating system, apply the same rules to measure the efficiency of the system: total energy output compared to energy input.	• Energy input of water heating system • Energy output of water heating system	
Equipment level	Pumping System Energy consumption	Filtration pumps run 24/7 and are one of the largest electricity consumers.	• Electricity consumption of filtration pumps	**Quarterly basis:** Review the monthly or weekly electricity consumption. An increase in energy consumption can be due to increase in backwash cycles, performance deficiency of the pump, or change of pump settings.

	Indicators	Description	Data required	Reviewing frequency and how do you use data
Other equipment and area	Energy consumption	Other energy consuming assets or areas such as office, gym, sauna, HVAC, and lighting can represent a significant portion of the total energy consumption of the pool. However, the value in monitoring the actual energy consumption might be minimal. You should evaluate the potential cost-benefits of adding additional metering.		**Quarterly basis:** Review the monthly or weekly energy consumption of other equipment or areas to detect possible energy increasing trends.
Pool level	Pool makeup water	For indoor pools, the evaporation rate is fairly constant over the year. The monthly amount of water consumption for pool makeup should vary mostly based on backwash. For outdoor pools, however, the evaporation is more dependent on the weather conditions, and could be correlated to Heating Degree Days.	• Water consumption for pool water makeup • Heating Degree Days from Bureau of Meteorology	**Quarterly basis:** Review the monthly average water consumption per patron. An increase in total water consumption can refer to leaks, incorrect backwashing procedures, or an increase of water evaporation.
Domestic water usage	Domestic water and Domestic Hot Water usage per attendance	The amount of water used per patron is the most accepted tool to monitor the water efficiency of an aquatic centre.	• Water consumption for domestic use • Attendance of the site	**Quarterly basis:** Review the monthly average water consumption per patron. An increase in consumption may be related to leaks.

Appendix 2 – Typical metering arrangements for aquatic centres at site level (gas boiler)



A

Gas meter to monitor the gas consumption of the boiler supplying heat to the pool hall. The gas consumption should be correlated to weather conditions. This correlation can be used to monitor the performance of the pool hall heating system.

B

Gas meter to monitor the gas consumption of the boiler over time. If the thermal output is monitored, the efficiency of the boiler can be estimated.

Make up water meter used to measure the water loss over time (from evaporation and backwash).

Flowmeter to verify the pool turnover is compliant with regulatory guidelines.

Energy meter to monitor the electricity consumption of the filtration pumps over time.

Two temperature sensors. The flowrate can be estimated from the heating boost pump speed to measure the heat transfer in the heat exchanger.

Pump

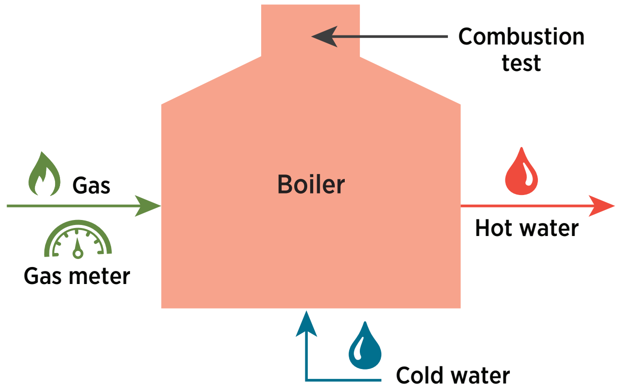
Appendix 3 – Metering arrangements for typical water heating systems

3A: Gas boiler

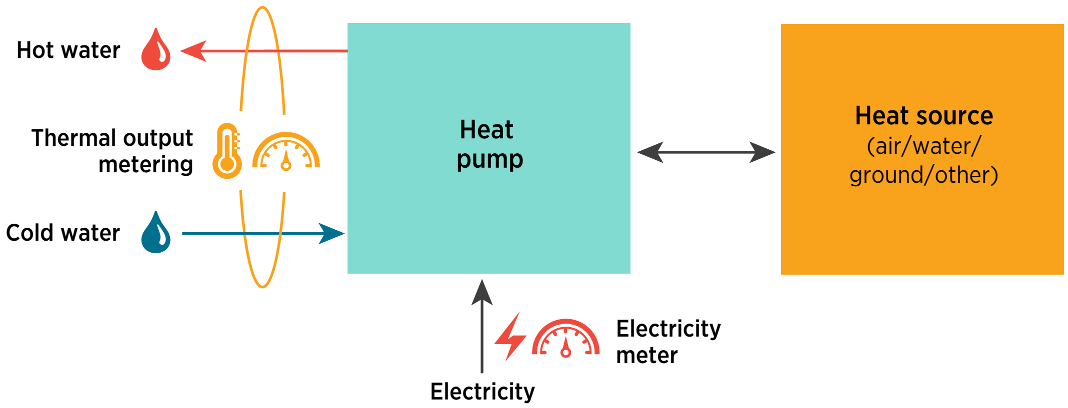
Gas Boiler: input and efficiency

Combustion efficiency test should be performed on a regular basis, at least annually, by a professional to verify the correct settings of the boilers and the efficiency of fuel combustion.

For the selection of a gas meter, please refer to I am your gas measurement and monitoring guide.



3B: Electric heat pump



The thermal output can be monitored by a combination of a flowmeter and temperature sensors. It is the ideal option, but the flowmeter is an expensive device requiring routine calibration.

Indirect measurement option 1: The flow rate can be estimated based on the specifications of the boost pump. Then, only two temperature sensors on the water flow going in and out of the heat pump are required.

The electricity input can be measured by a power meter.

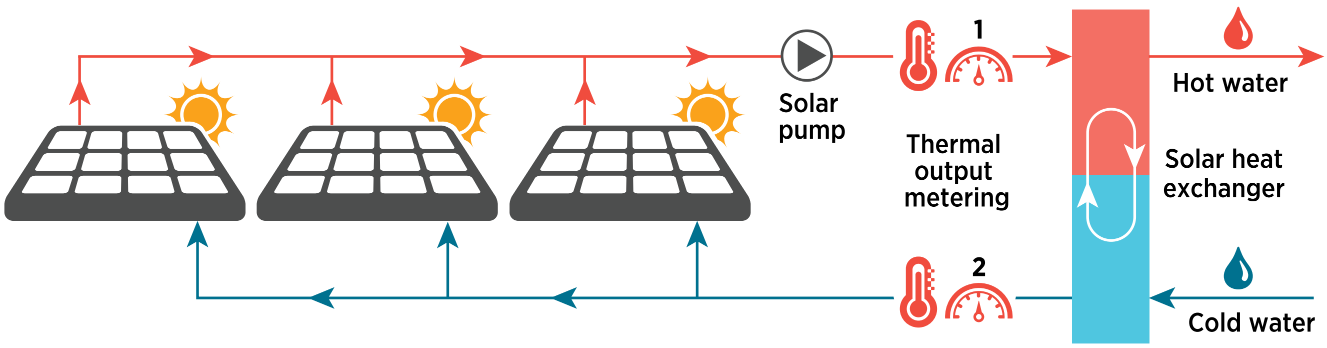
Indirect measurement option 2: if the heat pump is fully monitored, and depending on its configuration, it might be possible to estimate the electricity consumption based on the number of compressors running or the VSD speed of the compressor.

The coefficient of performance (COP) of the heat pump can then be calculated based on the following equation:

$$\text{COP} = \frac{\text{Thermal output (kWh)}}{\text{Electricity input (kWh)}}$$

For the selection of an electricity meter, please refer to the OEH Electricity metering and monitoring guide.

3C: Thermal solar system



For a thermal solar system is it recommended to monitor the thermal output on a daily basis based on the rated pump flow rate combined with temperature differential. The daily or monthly thermal output can be correlated to the solar exposure measured by the closest weather station. Over time, if the solar system loses efficiency the following ratio will decrease. The performances of the system can be calculated based on the following equation:

$$\text{Efficiency} = \frac{\text{Solar exposure (MJ/m}^2\text{)}}{\text{Thermal output (MJ)}} \times \text{Total solar system surface area (m}^2\text{)}$$

Efficiency to be calculated on a daily or monthly basis.

3D: Filtration pumps and domestic hot water systems

Filtration pumps: input only

Filtration pumps run 24/7 and are one of the largest electricity consumers. The total energy consumption should be monitored and compared on a monthly basis in order to observe trends (increases or decreases in energy consumption).

The electricity consumption can be either measured by a power meter (most accurate option) or through the VSD (cheapest option).

Note: meters should not be located close to chlorine facilities as the chlorine will quickly corrode a meter's sensitive electronics.

Domestic hot water boiler

For a domestic hot water boiler, it is usually cheaper to measure the water flow going into the boiler rather than the gas flow. In this case, the gas consumption can be estimated based on the rated efficiency of the boiler and the heated water volume.

Appendix 4 – Typical metering and monitoring cost

Costs to purchase and install metering is highly situation dependent. Below is a guideline only.

Table 3 Typical metering and monitoring costs (including meter supply and installation)

Item cost	Cost range per unit
Pressure sensor	$100 – $500
Temperature sensor	$100 – $500
Gas meter	$1000 – $8000
Water flow meter	$1000 – $5000
Basic electricity meter	$200 – $800
Power quality meter	$1000 – $3000
Networking equipment (total)	$2000 to $10,000
Installation (per meter)	$500 to $3000
Software or online platform subscription fees (per meter point)	$100 to $1000

Additional information can be found here:

- OEH Electricity metering and monitoring guide
- OEH Gas monitoring guide