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Water Efficiency and Water-Energy Nexus in Building Construction and Retrofit

IO3. Training Courses Curricula, Contents and e-Learning Platform

Training materials for the WEE's Course

TRAINING HANDBOOK Proposal

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Partnership:

- Agência para a Energia - ADENE (Portugal)
- Fundación Laboral de la Construcción - FLC (Spain)
- Ente per la Formazione e l'addestramento professionale nell'edilizia -FORMEDIL (Italy)
- Centre for Renewable Energy Sources and Saving – CRES (Greece)

Disclaimer: contents developed in this handbook proposal need to be carefully revised before being used as training materials or directly. Please contact the specific partner teams for any comments, suggestions or enquiries regarding specific modules of this handbook. Also notice that local, national and international standards should be carefully followed and considered.

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This training handbook proposal is part of the IO3 - Training Courses Curricula, Contents and e-Learning Platform.

Contents

WATER EFFICIENCY EXPERT COURSE TRAINING CONTENTS

SUMMARY

The curriculum for the 'Water Efficiency Expert' (WEE) consists of a total of four (4) Modules, each of them consisted by 3 to 6 learning Units (6 for Learning Unit 1, 4 for Learning Unit 3, and 3 for LUs 2 and 4), with an overall learning time of **50 hours of learning**. As analytically presented in the below aggregate table, out of the total time of the 50 learning hours allocated, the 20 of them will be the so-called 'contact hours', i.e. the hours during which in-classroom (face-to-face) of training or any other way of 'supervised' training (e.g. e-learning) will be provided, while the assessment / examination of the participants in the course(s) will last for 3 hours.

	Contact hours	Hands-on hours	Self-study hours	Assessment hours	TOTAL
Module 1: Design of water efficient buildings	8	4	7	1	20
Module 2: Supervision during the construction, commissioning and operation of a project	4	2	3	1	10
Module 3: Water measurements and water-energy nexus	4	2	3	1	10
Module 4: Communication with customers/consumers	4	2	4	0	10
TOTAL:	**20**	**10**	**17**	**3**	**50**

It should be stated that the proposed WEE course may be ambitious to some of the courses that are usually taken e.g. for engineers considering water and energy building systems. This was intended, as it should represent an upskilling standard for both starting a career and long lifelong training. It should be highlighted that the current proposal includes the water efficiency dimension, which in most cases is innovative in what regards the existing water and energy building systems curricula.

Regarding module development, Modules 1 and 2 were developed by CRES, while Modules 3 and 4 by ADENE. Please contact the specific partner teams for any comments, suggestions or enquiries regarding specific modules of this handbook.

MODULE 1: DESIGN OF WATER EFFICIENT BUILDINGS

SUMMARY

The design of a water – and energy, under the general concept of the Water-Energy Nexus - efficient building is addressed in the first module of the Water Efficiency Expert (WEE) Handbook. The structure and contents of this Module are of fundamental importance for the WEE, as it includes all the issues and subtopics that have to be properly addressed and furthermore analysed to achieve the design of a building that meets the necessary characteristics of water and energy efficiency as an asset.

In a general context, the WEE should contribute to properly designed hydraulic installations that are:
- ✓ characterized by excellent mechanical properties;
- ✓ fire resistant;
- ✓ impermeable and resistant to the impact of external factors;
- ✓ resistant to the fluctuations of pressure and temperature;
- ✓ manufactured with the use of globally approved materials, suitable for any type of application;
- ✓ resistant to wearing down and to changes caused due to strain;
- ✓ contributing to the protection of the environment and be constructed using recyclable materials;
- ✓ guaranteeing health protection issues;
- ✓ adequate to its main function of providing water and energy, under the water-energy nexus, efficiently, for residential buildings in quantity and under quality standards

In the 1st *Unit* the basics for the correct evaluation of the needs and site conditions to design a water-energy efficient hydraulic system as well as for the selection of its appropriate components are presented. The WEE trainees will thus enhance their abilities to design the water energy-efficient system and interpret its related available manuals, considering the water-energy efficiency requirements and the environment conditions (e.g. climate, orientation), to execute life-cycle cost analysis considering the possible lowering impacts of manufacturing process, transportation, construction, use, maintenance, reuse or disposal, to dimension of the sequence of pipe installations and the corresponding components, to limit obstructions and improve the piping network layout, and to provide work and cost estimation for the system implementation.

In *Unit 2*, the principles that a WEE trainee needs to know in order to be able to prepare and provide a list of the suitable materials and components in a water energy-efficient system, as well as to describe their correct positioning in the circuit, leading to an adequate selection and positioning of the different elements in the water energy-efficient system, of the functioning of fittings and other parts of the water-energy efficient system, of the applied methods and rationale for the designing/planning of the water-energy efficient system, as well as of the regulations and standards (local, national, international) applicable to water-energy efficient systems, are presented.

In the 3rd *Unit* of Module 1, the topic of the control and monitoring equipment is addressed. More specifically, the main functioning parameters of this kind of equipment together with its positioning in the circuit are showcased.

In *Unit 4*, the ways to indicate (to the customer) the maintenance, repair and replacement works (including costs) most likely to occur in the water-energy efficient system will be provided to the trainees in order to improve their knowledge of the methods for the identification of the leakages in the water-energy system, and of the methods for proper maintenance, repair and replacement of the water-energy system components. At last, the procedure for the preparation of a solid maintenance plan for an energy-water system is included.

In the *5th Unit* of Module 1 the topic of the designing of efficient systems for green areas and landscapes is showcased, including the principles and considerations and the basic design steps for green areas and landscapes.

Unit 1: Evaluation of the needs and site conditions to design a water-energy efficient hydraulic system and to select its appropriate components

Introduction / General description

In the first Unit of Module 1 of the WEE course, the basics for the correct evaluation of the needs and site conditions to design a water-energy efficient hydraulic system and to select its appropriate components are presented to the trainees in order to improve their knowledge of:

- evaluating the climate and site conditions necessary to the design (in terms of conception and sizing) of the water energy-efficient system (hydraulic, domestic hot water - DHW, grey water reuse, rainwater harvesting, irrigation) and the building load, based on provided correct information,
- the applied methods and rationale for the designing/planning of water-energy efficient systems, of identifying and applying adequate sizing tools,
- life-cycle cost analysis approaches and the most adequate evaluation strategies considering the environment and surrounding conditions,
- the work and cost estimation,
- the application of circular economy principles in construction,
- the applicable regulations and standards (local, national, international).

Scope – Expected results

After the end of attending this learning unit, the trainees will be able to:

- evaluate the climate and site conditions, as well as the building loads (thermal and water demand) (also applying circular economy principles during construction)
- implement methods for the design of the water energy-efficient system and interpret its related available manuals, considering the water-energy efficiency requirements and the environment conditions (e.g. climate, orientation),
- execute life-cycle cost analysis considering the possible lowering impacts of manufacturing process, transportation, construction, use, maintenance, reuse or disposal,
- dimension/size of the sequence of pipe installations and the corresponding components (using available tools)
- provide work and cost estimation for the system implementation

Key words / basic terminology

Site conditions, climate conditions, orientation, water efficient system, building loads, thermal energy demand evaluation, water demand evaluation, design and planning, sizing tools, life-cycle cost analysis, maintenance, reuse, disposal, circular analysis, piping network, regulations & standards.

1.1 Evaluation of the climate and site conditions

The evaluation of the climate and site conditions while designing a water-energy efficient hydraulic system consists of a very crucial step since it will be the basis on which the selection of the appropriate components will lay as well. This is the case, for example, in climates that are subject to freezing temperatures; in this case, all the components of the water system must be evaluated carefully, including storage, supply, waste, vent, and septic systems. The more extreme the conditions are the more critical the need for a properly designed system is. Proper plumbing design, materials, installation, and service will ensure that the water needs are met no matter which the conditions are.

1.1.1 Performing a typical site analysis

The understanding of the site and its environment is an integral part of a building program and it also is a prerequisite for a proper design. The building location on the site is basically established by one of two different viewpoints. In the first one, the building location is given by the client. In the second, and most advantageous, the building site is revealed by a thorough site analysis. A site analysis is the gateway to energy conscious design and environmental responsive architecture.

Site analysis is a predesign research activity that focuses on existing and potential conditions on and around the building site. It is an inventory of the site factors and forces, and of how these coexist and interact. The purpose of the analysis is to provide thorough information about the site assets and liabilities prior to starting the design process. Only in this way concepts that incorporate meaningful responses to the external conditions of the site can be developed.

A typical site analysis focuses on the existing and potential conditions around the building site. It typically includes the following: site location and size, neighbourhood context, zoning, legal aspects, geology, physiography (natural and man-made features), hydrology, soils, vegetation, wildlife, climate, culture, pedestrian and vehicular circulation, access, utilities, historic factors, density, sensory stimuli, and any other factor deemed appropriate for the particular site.

An understanding of these issues is important in designing a successful home that not only meets its internal responsibilities, but also relates well to its external environment. Since the building is aimed at remaining for many years, the analysis of the site should take into account not only the existing problems and capabilities, but also any future ones.

The purpose of using site analysis is to design a good correlation between the building and the site itself. The building design should be in harmony with those beneficial site conditions and strive to save, reinforce, amplify, and improve on what already exists. The analysis shall identify those site conditions that may be altered, eliminated, covered up, disguised or reformed.

In principle, care must be taken to take advantage of the good characteristics that nature has to offer and to protect against the inadequate aspects of the site. It is important to make these decisions deliberately and thoughtfully so that the effects of the building on the site are intentional rather than accidental or incidental.

All the factors needed for a complete site analysis can generally be categorized into aesthetic, cultural, and natural forces. Aesthetics has to do with what the residents think is beautiful (the designer has the responsibility to educate the client to possibilities); culture is the background of the people living in the area; and the natural factors are the background of the environmental elements. For the purpose of water-energy efficient design, natural factors need to be investigated and understood. The natural factors that are most important regarding the thermal comfort in this analysis, can be listed under climate and microclimate.

1.1.2 Understanding of the macroclimate and the general climatic characteristics

Each specific site has its own unique climatic characteristics that need to be analysed. The climatic aspects of the specific site or areas on the site are called the microclimate. The specific characteristics of the site are analysed only after one has a good understanding of the macroclimate and general climatic characteristics which give an overview of the climate for the specific region.

The microclimate must be studied not only for the natural elements, but also for how any man-made elements, such as buildings and landscaping are affecting and/or will affect the site. For example, a windbreak that protects against the winter winds may significantly change the microclimate of the site (see Figure 1.1).

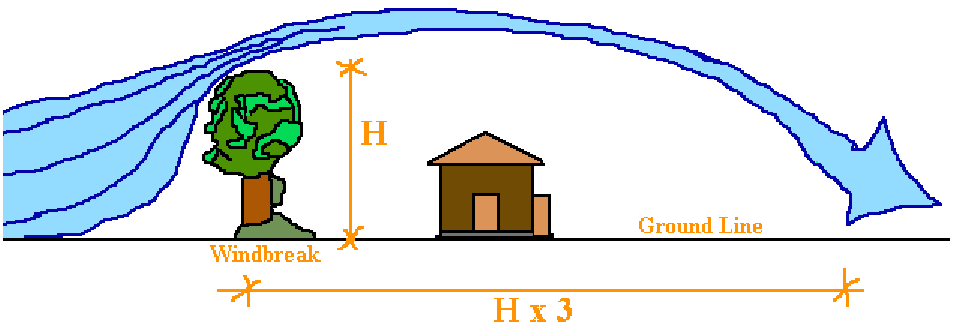


Figure 1.1: Windbreak illustration

[Source: https://www.learningwithexperts.com/gardening/blog/what-is-a-microclimate]

The climate elements that may be addressed in this analysis include: the sun, wind, humidity and temperature, as well as rainfall (due to its importance for irrigation, rainwater harvesting systems, etc.).

Climate elements

Sun

The sun's movement on the site will be the same as that shown in the available sun diagrams (see Figure 1.2). Existing elements (natural or man-made) on and around the site will have definite shading patterns. Understanding those patterns can help determining the building location and configuration. For any given spot on the site, one can draw the existing elements on the sun graph grid. Just as the sun path was plotted by knowing the azimuth and altitude of the sun, existing site elements can also be drawn on the graph from any one spot on the site. Thus, the diagram can show which locations on the site receive sunshine or shade. These same diagrams can be used to determine shadow patterns to be drawn in plan.

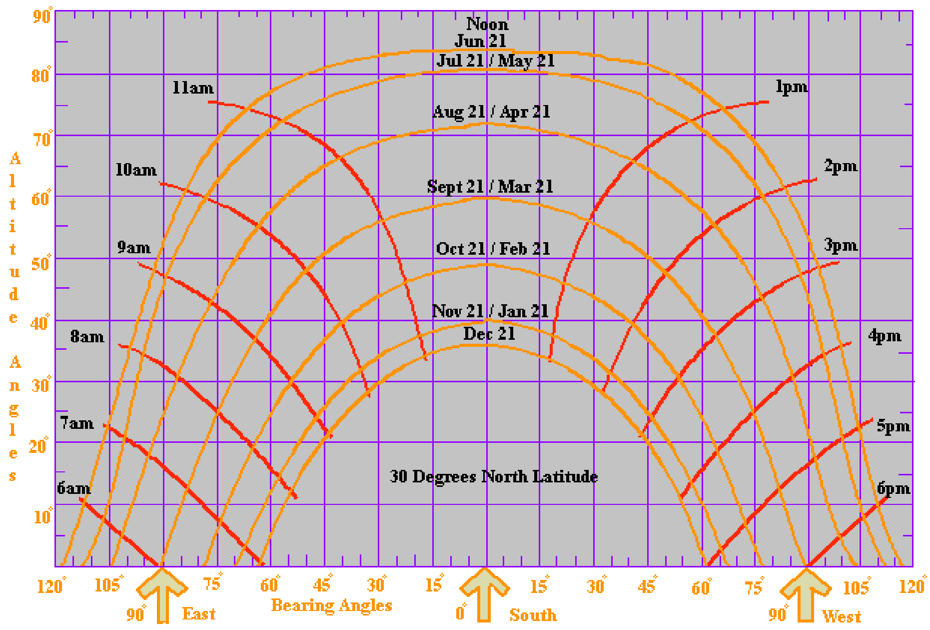


Figure 1.2: Sun Chart for 30° North Latitude

[Source: http://www.dnr.louisiana.gov/assets/TAD/education/ECEP/drafting/f/app-c.htm]

Wind

Wind at the site and at different locations on the site can vary from the general wind data given for the area. A better understanding can be obtained by testing a true scale model of the site and its buildings in a wind tunnel. In the case that wind testing is not feasible, the designer can understand wind direction and speed by using five basic principles of air movement: velocity, direction, pressure, density and the venturi effect.

First, because of the friction, the air velocity is slower near the surface of the Earth. The cause of this reduction in velocity is the roughness of the ground, including contour changes and vegetation configuration. Ground wind velocities measured at the site are frequently much lower than those measured at the top of an airport tower. As consequence, any sites or buildings that are exposed at altitudes higher than the airport tower are likely to experience much higher wind velocities.

The second principle is that air tends to continue moving in the same direction even when it encounters an obstruction. As a result, it tends to flow around objects, rather than reflecting off the objects. Third, air flows from high-pressure to low-pressure areas. For example, a positive pressure being built up on the windward side of a structure and a negative pressure being created on the leeward side create cross ventilation.

The fourth principle of air movement is convection, which involves the temperature and density of the air. For example, air flowing from a forested area to a meadow will tend to rise because air in the meadow is exposed to more solar radiation, making that air less warm and dense.

Finally, when the airflow is channelled and restricted, the pressure rises and the velocity increases. This is called the venturi effect (see Figure 1.3).

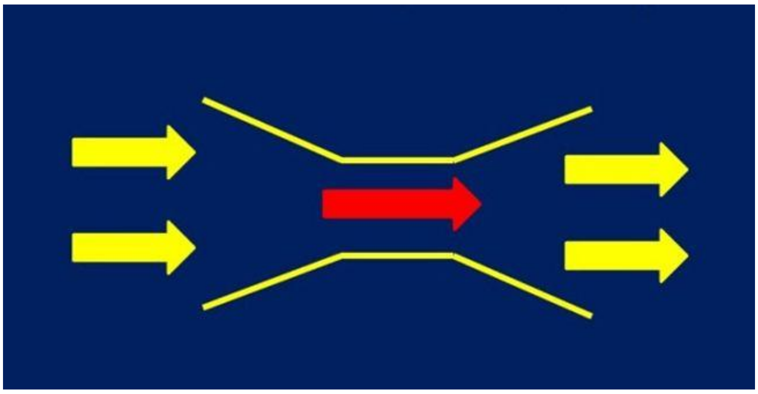


Figure 1.3: Venturi effect in wind motion (wind acceleration through narrow passages)

[Source: https://www.weathergamut.com/2018/03/06/weather-lingo-venturi-effect/venturieffect/]

By using these principles and understanding how air moves and acts similar to fluids, like water, wind patterns on different sites and in different conditions can be visualized. These patterns can be reflected to the existence of local winds, which generally move short distances and can blow from any direction. Similarly to the global winds, most local winds result from the differences in pressure caused by the uneven heating of Earth's surface. However, these pressure differences may result from a different process. The pressure differences that cause local winds are caused by the properties of the matter that makes up Earth's surface. For example, some materials, such as rock, heat up more rapidly than other materials. Areas of low pressure form over material that heats up quickly.

As a consequence, the wind pattern near large bodies of water is generated by the heat gain, heat loss, and heat storage variations between land and water. Water has more stable temperatures. The wind is usually moving toward the land during the day when the land is heating up faster than the water and when the water is absorbing solar heat. At night the direction is reversed, with the breezes flowing from the land, as it cools, to the water, as it radiates stored heat to the night sky (see Figure 1.4).

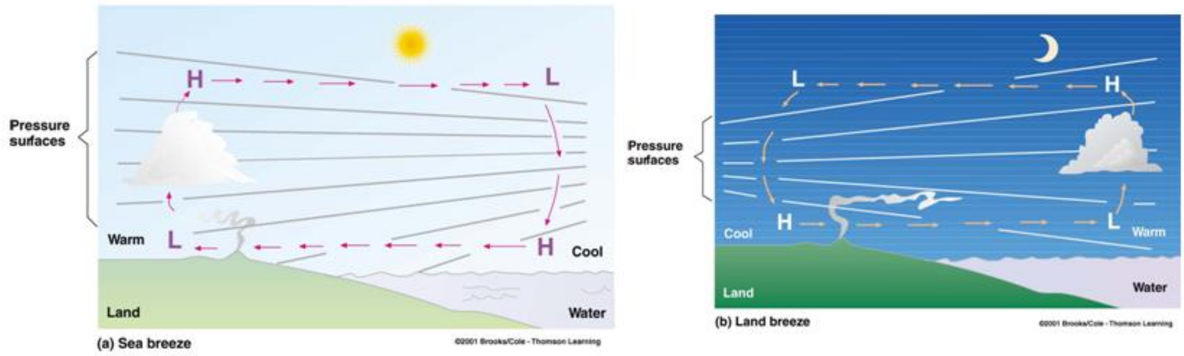


Figure 1.4: Land and sea breezes caused by the differences in temperature over land and water

[Source: www.weather.org]

In valleys, the wind moves uphill during the day as the sun warms the air (the air along the mountain slopes heats up rapidly) causing it to become less dense. This warm air that rises up the mountain slopes, is creating a valley breeze. At night, the air along the mountain slopes cools. This cool air moves down the slopes into the valley, producing a mountain breeze. Pockets or lakes of this cool night air can be damned just as water can (see Figure 1.5).

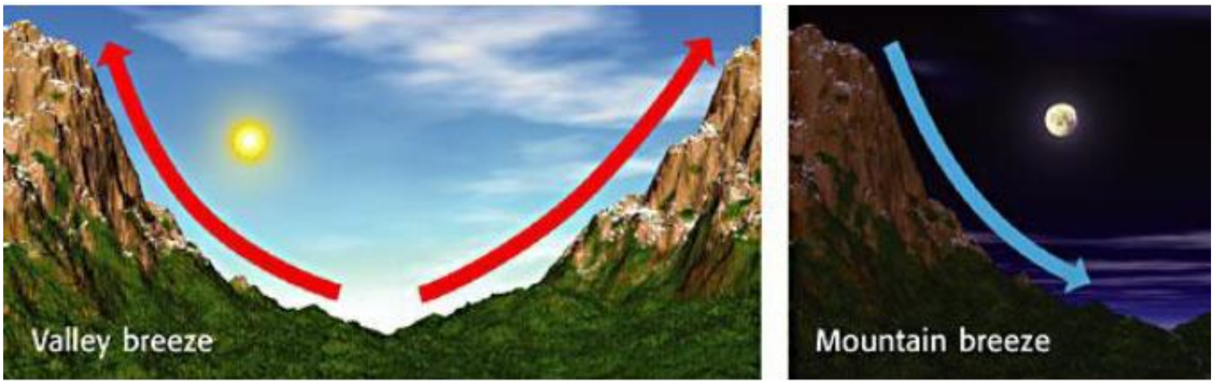


Figure 1.5: Formation of valley breeze and mountain breeze

[Source: https://midwaymsscience.weebly.com/uploads/8/2/9/8/8298729/section_3_-_air_movement_and_wind.pdf]

One of the most important principles for ventilation in buildings is that high pressure and low-pressure areas develop around an object that obstructs the path of airflow. Some of the aerodynamic principles that result are that the windward side usually creates a high-pressure area as air stacks up and attempts to move around the object, creating a cavity of negative pressure (low-pressure area) on the leeward side of the object. The velocity of air movement increases as it rushes around and over an object, while it can also create a dead air space on the leeward side of the object.

Humidity

Sites located near large bodies of water or rivers tend to be more humid than inland areas. Water vapour is a gas that occupies the same space with other gases that together constitute the air. However, in some ways, water vapour acts independently of the air. For any given temperature and degree of saturation, water vapour in the air exerts its own vapour pressure. It flows or migrates from areas of higher vapour pressure toward areas of lower vapour pressure in air or in materials. Moisture, driven by vapour pressure, can even travel through porous materials through which air cannot pass. Wind direction also affects humidity. Downwind from the water is more humid than upwind. Vegetation also increases moisture in the air.

Temperature

The microclimate temperatures of the site may be different from the general data collected at the nearby airport and can vary significantly at the site. Again, large bodies of water will tend to stabilize temperatures on the land adjacent to them.

Through evapotranspiration, trees and other vegetation tend to lower the temperature of the air around them. A moist lawn is 12° to 9°C cooler than bare soil and 1°C cooler than unshaded asphalt. The shade temperature of a large tree can be 12° to 9°C cooler than the unshaded lawn during a summer day. Sites with a more southern slope will be warmer than a flat site because radiation from the sun is more perpendicular to its surface. Likewise, a northern sloping site would not receive as much radiation and would therefore be cooler.

Rainfall

The amount of rain, the type of pavement (permeable and non-permeable areas), and the available irrigation area are important to understand supply needs. Rainfall indexes differ from place to place in terms of amount and annual dispersion, with more extreme events taking place due to climate change issues. Also, but depending on the local circumstances, there can be low or extensive evaporation, permeability, etc. The availability of rain is important to address the irrigation needs of the outside areas and to analyse the relevance of installing a rainwater harvesting system. This may be important in residential single-family buildings, where there can be more available room to perform the installation and the rainwater network is more easily designed.

1.2 Evaluation of building loads

In the frame of the Energy Performance of Buildings Directive 2010/31/EU (EPBD), requirements for new and existing buildings within the EU have been developed. Accordingly, the building systems designers must optimize all possible aspects (building envelope, shadowing, heating and cooling system components, regulation criteria, etc.), starting from the earliest design phase to respect the prescriptions of the current directive and to simultaneously ensure the thermal comfort of the building's occupants.

The evaluation of the loads of a building, both as far as (thermal) energy and water demands are respectively concerned, consists of a necessary step of the entire evaluation procedure of the needs, in the frame of the design of efficient water–energy hydraulic building systems. On the other hand, the procedure of a detailed assessment of the energy/water performance of a building requires a large amount of input data regarding the building typology, the environmental conditions and the thermo-physical properties of the envelope, the geometry, and many other parameters.

1.2.1 Thermal energy demand evaluation

The heating and cooling loads are the measure of energy needed to be added or removed from a space by an HVAC (Heating, Ventilation, and Air Conditioning) system to provide the desired level of comfort within a space. It is important to notice here that, a correctly designed HVAC system saves not only energy (that will be otherwise be wasted), but also water, as the main way of transferring the heat inside a building is (still) water; so the less water needed to be heated (or cooled) the better and more efficient will be the use of water within the building's network.

The thermal needs (thermal energy demand) of a space and/or a building in a more general context are defined as the amount of heat that should be taken as a basis for designing a heating installation. They are a property of the space or building, thus they are independent of the heating system that is potentially going to be installed. They depend on the size of the space, on the way the walls are built, on the size and the material of the openings, on the ventilation mechanisms and characteristics as well as on other factors.

The calculation of the thermal energy demand has to be performed for each space of the building separately, so that the size of the radiators in this respective space to be determined. The total thermal needs of the building result from the sum of the individual thermal energy demand of all the heated spaces. Before calculating the thermal needs of a new building, the thermal insulation issue must be checked, i.e. all the requirements of the Building Thermal Insulation Regulation that is in force must be taken into account.

The actual heat loss of a building is lower than the amount of heat that a heating installation can provide. This is due to the fact that the design of the installation is done so as to cover the losses of the building even at the minimum possible values of the outside temperature (average minimum outside temperature of the area). The thermal needs of a building are at the same time the maximum heat losses.

The methodology for calculating the thermal energy demand is based on the laws of heat transfer. However, as during the calculations many quantities/properties/characteristics have to be determined and selected, such as e.g. space temperatures of various uses, quantities of ventilation, etc., to avoid arbitrary assumptions, the various countries have established a single method of calculation given in the form of a regulation. These regulations may vary from country to country.

Depending on the regulation, the method for calculating the thermal needs also differs. In general, the most widely used calculation method is the one referring to the two versions of the German DIN 4701, which have been differentiated by the impact of the energy crisis and the evolution of automation. Thermal losses can also be calculated based on the ASHRAE method, which generally does not provide for increments and calculates ground losses differently than the DIN 4701. In general, this method is simpler to apply and can be used in combination with the calculation of cooling loads.

Thermal losses are calculated for a permanent heating state, i.e. it is assumed that all the quantities included in the calculations remain constant over time. It is also assumed that the temperature on the surfaces of the partition walls bordering heated spaces is the same as the room air temperature. Thus the inner walls exchange radiation only with the inner surface of the outer walls.

The normal heat needs do not necessarily correspond to the actual heat needs. If e.g. heating surfaces with a high percentage of heat transfer are placed in front of the windows, the losses of the space will be greater. Such cases should be avoided so as not to waste energy. In general, the total heat loss of a space is due to conductivity losses and ventilation losses. Thermal conductivity losses must be calculated separately for each structural element when there is a different coefficient of thermal conductivity or a different temperature difference.

The calculation of thermal ventilation losses is based on a simplified simulation of determining the amounts of air entering from the joints of the openings of the space. The calculation takes into account the pressure differences created by wind buoyancy and thermal buoyancy as well as the flow resistances through the joints of the internal and external structural elements of the space (windows and doors). When the ventilation is forced (mechanical ventilation with the help of fans), the extra amount of air entering the space is taken into account.

Values resulting from the calculation of heat losses with the help of regulation (normal thermal needs) ensure a satisfactory heating installation, because the minimum outside temperatures, the speeds of the most frequent winds during the winter, the heat capacity of the building, the tightness of the windows, etc. are taken into account. Obviously, during the construction of the building care should be taken to ensure the values of the quantities taken into account in the calculations. Thus, in addition to selecting the appropriate method for calculating heat loss, it is necessary to collect the necessary data regarding the external temperature, wind speed, the way the building is constructed in terms of tightness and the mode of operation (continuous or intermittent) installation, to ensure adequate heating efficiency at all times.

Also, in addition to adequate heating, the purpose of the calculations is to ensure uniform heating in the building based on the required internal temperatures. This is possible within certain limits and depends mainly on the thermal behaviour of the building and the choice of automation/controls and how they function.

Another aspect that is of importance in the calculation of the thermal needs of a building is that of Domestic Hot Water (DHW) demand (Sanitary Hot Water). Actually, there are many methods (at least Four) for calculation of the energy requirements of the delivered domestic hot water. The methods differ as to the level of detail assumed for the domestic hot water demand. For example whether the conditions relating to the different uses of the hot water are taken into account. A national Annex may specify which method should be used for different building types. A national Annex may also specify which method is acceptable for the purpose of energy labelling or any other specific use.

Evidently, the building heat demands are a main issue mainly in the northern European countries (where colder climates and longer winter seasons emphasise the demand for these energy services). Nevertheless, since building heat demands reflect also the levels of building insulation, the levels of energy services available and desired, the levels of comfort etc., no such clear division currently exists in Europe. Quite contrary, building heat demands are substantial also in central and, to some extent, in southern European countries as well. In the future, by refurbishments of the current building stock and by new construction of low energy houses, the heat demands of European buildings are expected to decrease. However, since in parallel, specific buildings spaces and the use of domestic hot water are expected to increase, the future heat demands of European building remain difficult to predict.

1.2.2 Water demand evaluation for specific types of buildings

The water demand evaluation is a long procedure that is composed of separate and detailed steps, finally leading to the estimation of the use of water performed by all the equipment/devices using water in the building. The building water system that is herein addressed is the residential building type, supplied by a public water supply network. Under the standard conditions of flow and pressure guaranteed by the utility, the connection may be done directly through the pipe. In the case that water needs to be accumulated in reservoirs or be pressurized by a pumping system, the constructive aspects and maintenance procedures of these should be carefully undertaken. The elements that should be considered to the designing of a building network include the distribution pipes and accessories (valves, pumps, fixtures and equipment).

As a starting point a walk-through is typically necessary, to record detailed information on each piece of water-related equipment and determine the condition and operation so that the water use can be estimated. This initial step includes:

- ✓ Recording hours of operation and operating schedules,
- ✓ Measuring water flow rates,
- ✓ Documenting equipment condition,
- ✓ Recording equipment information such as model number and manufacturer, and

- ✓ Identifying efficiency opportunities such as low and no cost measures or retrofit and replacement options,
- ✓ Checking the available options to include improve resilience in buildings, namely opportunities for installing rainwater harvesting or grey water systems,
- ✓ Interacting with the local water utility to undergo project supervision and commissioning.

Following the collection of the relevant information regarding each component of the water-using equipment, a *water balance* has to be developed, which shall compare the total water supply baseline to water that is used by fixtures, equipment and applications. A water balance collects information from multiple sources to examine how water is used at each facility. Thus, first the *water demand* has to be efficiently estimated, and the determination of the water use of all equipment or application using water has to be performed.

The following suggested five steps outline the process for determining water use at the equipment level:

1) Creation of an inventory of all water-using activities and reused water possibilities.
2) Documentation of the results of the walk-through survey for each equipment type, including the operating schedule, flow rate, model number, and condition of each piece of equipment.
3) Obtaining of any available equipment sub-metered data to quantify the particular use.
4) Evaluation of the seasonal patterns in the monthly water-use data and comparison of those data to the inventory of uses. The seasonal pattern of water use can help quantify water uses that are typically seasonal, such as irrigation or evaporative cooling systems. This is also important to evaluate the potential of installing a rainwater harvesting system, with basis on the rainfall index.
5) For unmetered water end uses, the WEE should make an estimation of the water use:
    - ➢ The water use from plumbing fixtures (i.e., toilets, urinals, faucets, and showerheads) can be estimated based on the flow rate/flush rate of the fixture and the number of occupants and daily use per occupant.
    - ➢ The cooling tower water use can be estimated based on cooling capacity and load factor.
    - ➢ The irrigation water use can be estimated based on irrigated area and inches of water applied by the equipment, also considering climate elements such as rainfall.
    - ➢ The kitchen and laboratory equipment water use can be estimated based on water use per cycle and the frequency of cycles.

After the identification of water demand, the next step is to create the water balance with the quantified water uses by major equipment type. For this reason, the sum of the end-use water consumption has to be compared to the total supply. The difference between these two values represents the unknown water uses in the system, which could be a result of either water leaks in the distribution system or equipment, of inaccuracies in the engineering estimates used to determine equipment water use, or of accounting errors, such as poorly calibrated meters or unit-conversion problems.

If the unknown amount in the water balance is more than 10% of the total water supply, further investigation is probably requested to find the cause of the imbalance. This can include a comprehensive leak-detection program. Additionally, the water balance will uncover the high water-use activities, which will help in prioritizing water-saving opportunities.

The hydraulic calculations and dimensioning aspects of the system should be addressed in the project layout and be validated under regulatory standards. In this process, the water utility should be contacted to project supervision and guarantee that no contamination with potable water network takes place. This is particularly important when the installation of reuse water systems is considered (e.g., rainwater, greywater).

1.3 Available methods for designing of water-energy efficient systems

1.3.1 Methods and rationale for the design of an efficient water heating system (for space heating and DHW)

Several factors have led to a general industry resistance to initially perform an accurate load calculation, which is necessary for the design of a right-sized HVAC system. Historically, energy codes did not address stringent levels of energy efficiency, and rules of thumb were developed for HVAC sizing that worked based on the construction at that time. Building enclosures have become more and more energy efficient as energy codes have become more stringent the last years, but these rules of thumb have not changed. Full credit should be taken by the HVAC system designer for improvements such as better windows, enhanced air tightness strategies, and additional insulation.

Data

The following data should be available to calculate the building's thermal needs:

a) Location plan of the building: The plan should show the North. In addition, the heights of the neighbouring buildings are needed.

b) Floor plans and sections: From these plans / drawings, all the dimensions of the spaces and their openings should be easily located. The drawings should also show the uses of all areas of the building (e.g. office, classroom, etc.).

c) Description of building construction: This is a basic document prepared by the architect. The construction description gives all the details of the construction of the walls, such as e.g. thickness and materials of the various layers, coefficients of thermal conductivity, etc. The description of the windows includes data on the material of the glazing, the frame, the joints, etc.

d) Climatic data: These are the average minimum outside temperature, as well as the direction and intensity of the prevailing winds.

Thermal capacity of the boiler

The calculation of the thermal needs of a building ends with the calculation of the thermal capacity of the boiler. The heat required to heat the building is produced in the boiler and must be transported to the radiators in each space/room. For the transfer of heat, mainly water circulating in the piping network is used. In some cases air is used as a heat transfer medium, so an air duct installation is required.

The heating power (capacity) of the boiler is given by the relation:

$Q_K = Q_N \cdot (1 + z_R)$

Where
Q_N = the normal thermal needs of the building
Q_K = the normal heating power (capacity) of the boiler
z_R = a premium that takes into account the thermal losses of the piping network (or air ducts)

The values of the z_R factor are selected as follows:

- For central heating, in which the central pipes are mounted on interior walls, are insulated and the distribution pipes are located in warm areas, it is obtained: $z_R = 0.05$
- For central heating, in which the central pipes are mounted on external walls, are insulated and the distribution pipes are located in warm areas, it is obtained: $z_R = 0.10$
- For worse installation cases of the piping network, it is obtained: $z_R = 0.15$

Because the power of the boilers is graded, a boiler with a similar (upward) power to Q_K is selected.

Going to DHW, the major determination in sizing water heaters is establishing the maximum probable demand. The design of a hot water service system may follow the procedure:

1. Determine the demand of hot water from the consumers - quantity and temperature.
2. Select the type, capacity and heating surface of the water heater (calorifier) - or heat exchanger.
3. Select the boiler (hot water accumulator).
4. Design the pipe scheme and the size of the pipes.

Water heater selection is best made on the basis of hot water usage. However, calculations may lead to a combination of tank size and heat input which do not exist. In this case, the tank size and/or heat input must be balanced to achieve the desired result. Therefore, it is necessary to understand that heat input provides hot water, at the hourly recovery rate, hour after hour. The storage tank represents instant hot water at greater-than-heater recovery.

The primary design objective is to ensure adequate supply of water to all fixtures at all times and at a proper pressure, temperature and flow rate. Especially important is the quality of service such as the wait time for hot water, water temperature (not too hot or too cold), and safety in operation.

1.3.2 Methods and rationale for the design of a water efficient hydraulic system

The design of a water efficient system may include the following aspects: the supplied water characteristics in terms of flow, pressure and water, the expected water demand in the building and the corresponding flow monitoring equipment. In addition, the distribution network characteristics (e.g., pipes, valves and fixtures), comfort levels and quality of the distribution system water availability, including the guarantee of adequate pressure, simultaneous use coefficients, thermal insulation or noise.

The water efficiency planning should be incorporated in the early stages of a building development project. This is suggested basically for that the facilities most of the times tend to be oversized at the expense of water efficiency. There is the possibility that many building or system design synergies can yield substantial cost and efficiency improvements, but these must be done during the initial phase of the design process and before the experts are committed regarding the system choices. It is always clearly less costly to introduce a number of water efficiency measures during the design stage than to undertake retrofitting measures later on. The retrofits tend to be more difficult, expensive and intrusive to building operations.

In the designing / planning of a water-energy efficient system procedure, it is advised to apply the "Reduce, Reuse, Recycle, Restore and Recover (5Rs)" approach / concept for guaranteeing the quality and efficiency in building services. More precisely, the International Water Association (IWA) developed the 5Rs approach to water management for companies to consider and adopt as common practice. The entire water value chain, from source, through supply to consumers, needs to embrace the 5Rs as an approach.

In the "Business Guide" elaborated by the World Business Council for Sustainable Development (WBCSD) the following definitions of the 5Rs are used:

- Reduce: reduce water losses and boost water efficiency
- Reuse: reuse water, with minimal or no treatment, within and outside the fence for the same or different processes
- Recycle: recycle resources and wastewater (treated by membrane or reverse osmosis to a very high quality) within and outside the fence
- Restore: return water of a specific quality to where it was taken from
- Recover: take resources (other than water) out of wastewater and put them to use.

The 5Rs approach to circular water management, rather than approaches that look at water, energy and waste systems individually, minimizes pressure on water resources in terms of both quality and quantity. Effectively implementing the 5Rs can result in substantial savings in water, as well as energy, therefore reducing the environmental impact of both water discharge and the need to pump water over long distances.

Prior to the launching of any construction works, the developers are encouraged to examine the installation of an effective water treatment to treat the silty water and to use the treated water for non-potable purposes, such as construction use, washing, as well as to minimize discharge into the storm water drainage systems. The installation of intermediate tank(s) and pressure reducing valves (PRVs) at suitable levels of the water reticulation system within the building is a suggested and reliable method for the reduction of the water pressure.

Whenever a PRV is installed, a bypass arrangement shall be incorporated with the provision of a second pressure-reducing valve, as this will serve to facilitate isolation of any defective pressure-reducing valve for repair and replacement. A pressure indicator shall be provided for pressure monitoring and the associated pipes and fittings shall be able to withstand the maximum pressure that may arise upon the failure of the pressure-reducing valve. So, PRVs with expansion tank (for DWH) are suggested to be used in order to contribute to the regulation of the supply of water pressures within the distribution zones.

The PRVs must be installed at locations where the water fittings downstream of the distributing pipe would not be subjected to pressure head exceeding 25 meters, to prevent excessive deterioration. Master PRV outlets must use pressure regulating valves. Pressure reducing valves must be specified to operate at peak flow within the entire hydraulic range, from low hydraulic grade line (HGL) to the maximum working pressure of the system (high HGL, plus pump shutoff head for pressure boosted systems).

Another method for achieving the pressure reduction is the installation of intermediate tanks at suitable levels in high-rise buildings. In this case, the intermediate tanks installed at levels lower than the high-level water tank will serve water fittings at designated floors in the tall building. This should be addressed together with the water service provider, in order to assess the available network water pressure. All installations with non-potable uses should guarantee that no interconnections take place with the public water system, meaning that security valves or other equipment need to guarantee no-return should be placed and properly commissioned.

Domestic water system design

A domestic water system describes the indoor and outdoor potable water distribution system. It includes the connection to the water supply, whether it is an underground central city, county, state or federal distribution system or a private well. The domestic water system includes above-ground and below-ground piping, valves, fittings, ancillary equipment and the various plumbing fixtures that use the potable water. In Figure 1.6, an example of a domestic (only cold) water distribution system for a commercial kitchen is presented, as an example of how a domestic water system may be sized.

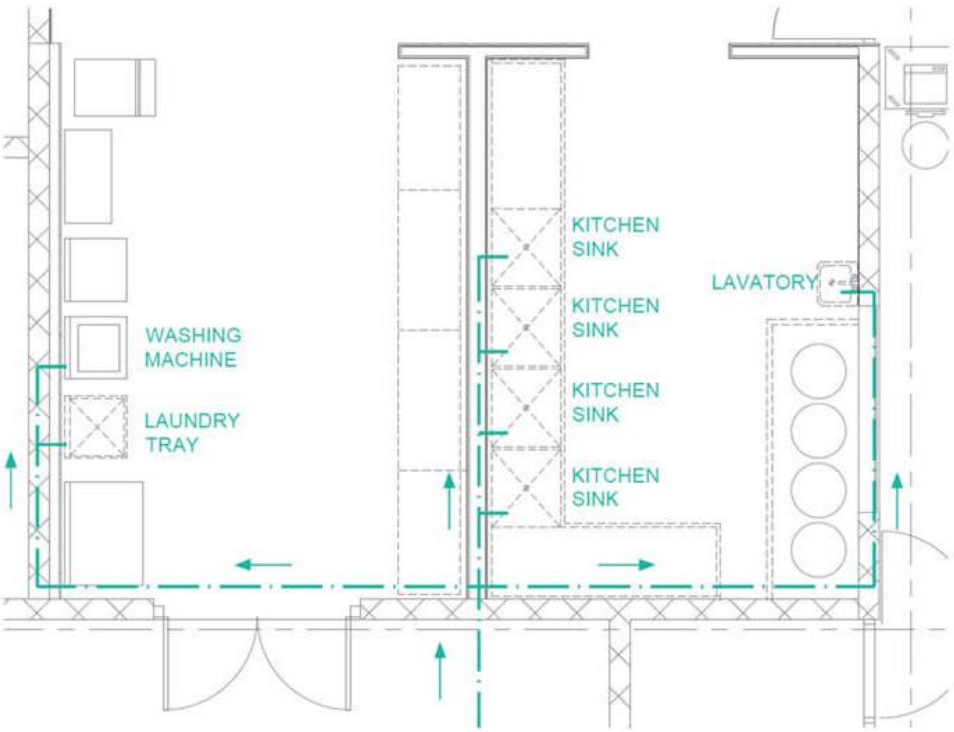


Figure 1.6: Example of a domestic water distribution system for a commercial kitchen

[Source: https://www.engproguides.com/domestic-water-piping-design.html]

As far as the sizing of water supply pipe lines is concerned, these must be sized according to the expected demand and not to the total theoretical demand from all fixtures simultaneously, while they must be based on the minimum pressure available for the building in question The designer must ensure that the required pressure is maintained at the most hydraulically remote fixture and that proper and adequate quantities of flow are maintained at all fixtures.

In addition, the designer must ensure that velocities amongst the recommended values are maintained in all piping. The velocity of water flowing in a pipe should not exceed 3 m/sec and should be designed for 2-2.5 m/sec or less, because high velocities will increase pipe deterioration, the rate of corrosion leading to pipe failure, and cause undesirable noises in the system and increase the possibility of hydraulic shock. Low velocities, in turn, may cause deposition and biofilm accumulation.

The designer should compute and/or know the following:

- ✓ Hydraulically remote fixture
- ✓ Available main pressure
- ✓ Pressure required at individual fixtures
- ✓ Static pressure losses (height of highest fixture relative to main pressure)
- ✓ Pressure loss due to friction
- ✓ Water demand (total system, and each branch, fixture)
- ✓ Velocity

<u>Hydraulically remote fixture</u>: The most remote fixture is the fixture that is the furthest distance away from the main domestic water supply point. The most hydraulically remote fixture is the fixture that is not necessarily the furthest away but the fixture that will have the least pressure given the projected water demand. For instance, a basement may be the furthest point but supplied with higher water pressure than the ground floor.

<u>Available main pressure</u>: The WEE will typically investigate the main water pressure available at the project site or that provided by the water utility. This pressure will determine the starting point for the pressure loss calculations. If there is insufficient pressure available to meet the pressure required at the individual fixtures, then a booster pump will be required. On the other hand, if the pressure is too high, then a pressure regulating valve will be required. High pressures at the plumbing fixture can lead to unsafe operation and unnecessary water loss while insufficient pressures may lead to discomfort and to extensive water usages for the same purpose.

<u>Pressure at individual fixtures</u>: The WEE should research the plumbing fixtures and determine the required pressure. For example, tank water closets only require 0.33 bars, while flush valve water closets can require 1 bar. Each plumbing fixture will have a different pressure requirement. Even different manufacturers of similar plumbing fixtures will have a different pressure requirement.

<u>Static pressure losses</u>: The static pressure losses are found by taking the difference between the initial elevation at the available main pressure point and the final elevation at the hydraulically remote fixture.

<u>Friction losses</u>: The friction losses are determined by finding the flow rate, velocity, pipe size, pipe roughness for the entire hydraulically remote run. Friction losses can be due to the viscous forces of fluid flowing through the pipe and similar losses through fittings like elbows and tees. Lastly, friction

losses are also due to miscellaneous equipment like water meters, valves, backflow preventers, pressure regulating valves, etc.

Water demand: The water demand is the projected flow rate. The projected flow rate is based on the water supply fixture units and any other continuously operated fixtures. The water demand is important because as the water demand increases, there will be an increase in friction losses. This will reduce the pressure at the hydraulically remote fixture. Thus, the water demand must be checked along with the pressure at the hydraulically remote fixture.

Velocity: Based on the water demand, the projected velocity can also be found. The velocity within the piping must be limited in order to avoid excessive noise, water hammer and increased pipe erosion.

Due to intermittent use of the fixtures it may be difficult to predict a rather realistic demand. The values indicated as an example in the table below are relevant for water supply lines in applications like houses, offices, nursing homes etc.

Copper Pipe Size DN *(mm)*	**Total Maximum Theoretical Demand Summarized** *(liter/s)* (gpm)	**Maximum Expected Demand** *(liter/s)* (gpm)
12	0.2	0.2
15	0.8	0.4
18	1.6	0.5
22	4.0	0.6
28	15	1.1
35	30	1.8
42	65	2.8
54	130	4.5

1 in = 25.4 mm

Main & branch pipe sizing

It is very difficult to quickly obtain the velocity, water demand, friction loss and static pressure losses within a piping system, just to size the plumbing lines. Often, estimates are used to size the main and branch piping, which can lead to inaccuracies and increased pressure losses or oversized piping. These estimates typically consist of a table of pipe sizes and the maximum fixture units that each pipe size can serve. The designer will sum the WSFUs (Water Supply Fixture Units) that are served by each pipe and then choose a pipe size that can accommodate the total WSFUs.

This process is exactly the same as the previous process, with a table and the maximum WSFUs for each pipe size. Except, the table can be customized for any pipe material, tank or flush valve and for any range of velocities and pressure drops. The previous process determined the maximum WSFUs for a pipe size based on some random velocity limitation and/or pressure loss limitation. However, higher velocities can be accommodated in certain areas where water hammer and noise are not an issue. Higher pressure drops can also be accommodated on piping that is not part of the hydraulically remote run.

In both processes, the piping layout must be completed. The piping layout consists of the geometrical arrangement of the pipes from the water supply to all plumbing fixtures. Three (3) main steps are described:

1) **Determination of the WSFUs:** it is defined by the Uniform Plumbing Code (UPC) and it can be used to determine water supply to fixtures and to their service systems. More specifically, there is a number of available tables where the total demand calculated by adding each "Water Supply Fixture Units" (WFSU) are compensated to an expected demand.

The table below can be used to size building supply and branch lines and meter and service lines.

Individual Fixtures	Minimum Fixture Branch Pipe Size	Water Supply Fixture Units *WSFU*	
	(inch)	Private Installations	Public Installations
Bathtub	1/2	4	4
Bathtub with 3/4" fill valve	3/4	10	10
Bidet	1/2	1	
Combination sink and tray	1/2		
Dishwasher, domestic	1/2	1.5	1.5
Drinking fountain	1/2	0.5	0.5
Hose bibbs	1/2	2.5	2.5
Laundry, 1 - 3 compartments	1/2		
Lavatory	1/2	1	1
Bar sink	1/2	1	2
Clinic fauce sink	1/2	3	
Kitchen sink, domestic	1/2	1.5	1.5
Laundry sink	1/2	1.5	1.5
Service or mop basin	1/2	1.5	3
Sinks, flushing rim	3/4		
Sinks, service	1/2		
Washup basin	1/2	2	
Shower, single head	1/2	2	2
Urinal, flush tank	1/2	2	2
Urinal, flushometer valve	3/4		
Wall hydrant	1/2		
Wash fountain	3/4	4	
Water closet, gravity flush tank	1/2	2.5	2.5
Water closet, flushometer valve	1	2.5	2.5
Water cooler	1/2	0.5	0.5

Source: Engineering ToolBox, (2008). Water Supply Fixture Units - WSFU. [online] Available at: https://www.engineeringtoolbox.com/Water-Supply-Fixture-Units-d_1073.html

2) **Conversion of the WSFU value to cubic meters per hour (m3 HR) or gallons per minute (GPM):** this volumetric flow rate will help to determine the pressure drop and fluid velocity within the pipe in the next and final step. The conversion from WSFU to m3 HR or GPM will depend on whether or not the connected fixtures are predominantly flush valve type or tank type.

A **quick sizing table** can be used to select the appropriate pipe size. The first step in using this table is to select the pipe material, pipe sub-type, predominantly tank/valve and the C-value.

Pipe Material	Copper
Pipe Sub-Type	Type K
Tank or Valve?	Valve
C-Value	150

The C-factor describes the pipe smoothness. Steel pipes are given a C-factor of 100 and smoother pipes have a higher C-value, while rougher pipes have a lower value. For example, copper's C-factor is typically 135 to 150, CPVC & PVC is 150.

3) **Determination of the acceptable velocities and pressure drops within the pipes:** This will vary between each situation and each company. Each company will have its own standards, but below is a brief discussion on the typical acceptable velocities and pressure drops.

The pipes that directly feed the fixtures are sized based on the table below. These pipes are the rough-in pipes that connect to the branch pipes and they shouldn't be confused with the fixture connection pipe. The fixture manufacturer will indicate the fixture connection sizes, but these sizes typically refer to the braided hose sizes and not the rough-in pipes. A rough-in pipe will typically be copper, which will be soldered to a dielectric union. On the other end of the dielectric union will be a threaded metal fitting. A shut off valve can be connected to this metal fitting, followed by a braided hose. The braided hose is then connected to the fixture piping connection. The size of the braided hose is determined by the fixture manufacturer.

Fixture	Minimum Pipe Size (in.)	Flow Rate (GPM)	Pressure (psi)
Bathtub	1/2"	4	8
Dishwasher	1/2"	2.75	8
Drinking Fountain	5/8"	0.75	8
Hose Bibb	1/2" Int, 3/4" Ext	5, 15	8, 15
Kitchen Sink	1/2"	2.5	8
Laundry	1/2"	4	8
Lavatory	3/8"	2	8
Shower	1/2"	3	8
Service Sink	1/2"	3	8
Urinal Flush Valve	3/4"	1.6	15
Water Closet Tank	3/8"	1.6	15
Water Closet Valve	1"	1.6	15

Source: Domestic Water Piping Design Guide, available at: https://www.engproguides.com/domestic-water-piping-design.html

1.3.3 Workload and cost estimations

During the preparation procedure for a water supply system implementation, a number of factors have to be taken into account. The operation and maintenance (O&M) costs need also to be determined during the preparation and planning phase. Another important aspect of the overall cost evaluation in view of the system implementation is the analysis of and identification of high cost areas which shall enable the system designers to more easily assess the impact of changes in the system operation. An early estimation of the recurrent costs will assist the water system designers to proceed with a sustainable project and avoid any necessary modifications in the future.

To reflect a labour cost of construction the following parts of a labour rate (per hour / day or month) are applied to the gross wage rate:

- Social security and medicare taxes that employers pay;
- Workmen's compensation insurance premium;
- Unemployment tax;
- Health insurance premium;
- Holiday and vacation pay;
- Retirement cost.

The estimated cost of labour is the labour rate multiplied by the estimated time to complete the work.

The operation and maintenance of a water-energy system involves the use of a variety of types of materials, which are usually categorised in supplies and spare parts. The supplies are usually referring to consumable items such as those that might be purchased in bulk and intended for a more general use (e.g. paint, cleaning rags, lubricating oil, common pipe fittings, etc.). The "spare parts" are referring to specific replacement components mostly associated with certain facilities, equipment or machinery (e.g. bearings, or other components).

The basic process for the estimation of material costs is described in the following characteristics:

✓ Details on all equipment, facilities and components of the system (*the most important regarding the engineering design process*)
✓ Details on the nature and the frequency of the O&M tasks to be performed
✓ Unit costs for parts and supplies to be used.

<u>Estimation of material requirements</u>

A good estimation of the equipment, the machinery or the facilities needed must be performed. Thus, the plan/study prepared by the designer shall include a complete design for:

✓ Intake structures
✓ Wells
✓ Reservoirs
✓ Pumping stations
✓ Transmission pipelines
✓ Elevated storage tanks
✓ Distribution piping
✓ Water meters
✓ House connections

The cost estimation on the above-mentioned items should not be made during the too early stages of the project planning, because the detailed engineering design may have not been completed, so only rough equipment and machinery lists may have been prepared. During the cost estimation procedure though, it is important to take care to be simply concerned with materials consumption, not inventories or procurement policy.

Some parts and supplies will be stocked, consumed, and reordered on a regular basis. Others will probably be purchased at the outset of a project but used only rarely. It is difficult to anticipate in advance which parts will be stocked in what quantities. Some initial stock of parts and supplies will be purchased, and these should properly be considered in the capital cost of the system. The concern here is the turnover or stream of materials used and the cost stream that produces.

Estimation of materials costs

The annual costs of the required materials can be listed, while for each item the annual quantity shall be multiplied by the respective unit price. The cost of each unit has to be available either from local suppliers or from records of previous purchases of those specific materials and, in this context, it is very important that the correct unit costs are used for the estimation procedure purposes. The unit costs vary widely with the quantity purchased, the lot size, the supplier, etc. At last, once all the appropriate costs for each unit have been collected, then the materials costs on an annual basis can be determined, by multiplication and summing.

1.3.4 Life-cycle cost analysis approaches

The life-cycle cost (LCC) analysis of a water energy-efficient system stands for the entire "lifetime" cost to purchase, install, operate, maintain, and dispose the whole system. The determination of a LCC involves following a methodology for both the identification and the quantification of all of the components involved in the LCC equation. While used as a comparison tool between possible design alternatives, the LCC process shall indicate the most cost-effective solution within the limits of the available data.

The components of a life cycle cost analysis typically include the initial costs, the installation and commissioning costs, the energy costs, the operation costs, the maintenance and repair costs, the down time costs, the environmental costs, and at last the decommissioning and disposal costs. The estimation of the cost of a specific project / design of a water energy-efficient system involves the matching of the specific information required by the project with a database of construction costs that are already known, in order for the engineer to be able to predict the cost of the project. In case that the project varies from the assumptions of the database, the predicted cost is adjusted appropriately.

For the case of hydraulic systems, the construction costs can be categorized as follows:

1. Materials: it includes the pipes, the fittings, the valves, the pipe supports, the sleeves, the low-voltage wiring, the fire stopping, the insulation, the drains, the cleanouts, the fixture carriers, the sprinkler heads, the medical gas outlets, and other similar commodity items as well as general material handling.
2. Preparation: it includes demolition work, excavation and backfill, cutting and patching, as well as survey and marking.
3. Fixtures: it includes the water closets, the lavatories, the urinal, the shower, and the service sink.
4. Accessories: this category includes the interceptors, the pumps, the alarms, the water meters, the backflow preventers, the pressure vessels, the water heaters and the water-treatment equipment.

One of the main parameters that consist an essential part of a life-cycle analysis performed for water hydraulic systems is the life-time performance of the pipes used for the construction of the network, including their expected failures, repairs and eventual replacement, as well as the associated costs (both direct and indirect) corresponding at each stage.

1.3.5 Application of circular economy principles in construction

The circular economy is an alternative to the traditional (linear) economy (make, use, dispose) in which the resources are kept in use for as long as possible, next the maximum value from them whilst in use is extracted, while finally products and materials at the end of each service life are recovered and regenerated. The circular economy aims at keeping products, components and materials at their highest utility and value at all times through life extension and maintenance, reuse, refurbishment, remanufacture and finally recycling.

As well as new design approaches, different business models are emerging to support the circular economy. This includes buying products as services, leasing, take-back, and sharing/asset utilisation models. The circular economy is not just recycling; it is looking at the entire life cycle of any process and considering how the best whole life outcome may be achieved. Resources are generally thought of in terms of materials (technical and natural), but the most holistic circular economy approaches also consider water, energy and ecology.

In construction, circular economy is about reducing the demand for non-renewable virgin materials, reducing the production of waste, and maximising the value of recovered materials used throughout all stages of the program: construction, maintenance and end of life. From a wider, built environment, perspective it goes beyond this and looks at circularity across other systems including energy, water, operational waste management, ecology, food, etc. To have maximum impact the circular economy needs to be considered throughout design, specification, procurement, and construction of the programme.

Some typical top tips that can be used towards circular economy principles implementation in buildings are the following:

1) Advise the client: Proactively identify where the project could benefit from circular economy design approaches and advise the client. For example, greater use of reused and recycled products, material efficient design, design to enable ease of maintenance and upgrade, design for adaptability and deconstruction, use of different business models etc.

2) Include the circular economy in design reviews: During the key stages of the practice's design review process, assess how well the design and specification addresses circular economy principles, and identify further opportunities for improvement.

3) Engage with manufacturers: Manufacturers have their own programmes of innovation and talking to them early in the design process may provide unimaginable opportunities. Ask manufacturers what actions they are taking to embed circular economy thinking in their product offer.

4) Align with the design life: Identify the design life the client has set for the building / asset and the different 'layers' of the building / asset (e.g. bridge structure 120 years, pavement 20 years). Align the design accordingly: identify the appropriate circular economy design principles for the lifecycle length. This should lead to material efficient design, less waste and higher levels of reuse over the building / asset's 2nd, 3rd, 4th life etc.

5) Design for ease of maintenance and upgrade: Design for ease of future maintenance and upgrade

work on the main elements, e.g. structure and services, to prolong the life of the building/asset and avoid waste. Ideally, asset managers/facilities managers and end uses should be engaged to help inform the design and specification from a maintenance perspective.

6) Design for future flexibility: Does the design brief include designing to enable future flexibility and reconfiguration of the building/asset? Think about the lifecycle of what is designed. Consider if it is appropriate and possible to design for future flexibility, to enable reconfiguration and reuse. Demonstrate the benefits of this approach to the client.

7) Design for deconstruction: Does the design brief include designing for deconstruction? This is commonplace for temporary buildings/assets, but at present, rare for permanent buildings/assets. Designing for deconstruction enables reuse of the whole building/asset, or individual components and materials at the end of life. Investigate for instance bolted connections and fixings, which enable easier dismantling and reuse.

1.4 Regulations and standards

1.4.1 Regulations applicable to the water-energy systems

The existing European regulations applicable to energy and other resources consuming energy-related products are the following:

- Directive 2010/30/EU of the European Parliament and of the Council of 19 May 2010 on the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products (No longer in force; Date of end of validity: 31/07/2017; Repealed by Regulation (EU) 2017/1369).
- Commission Delegated Regulation (EU) No 811/2013 of 18 February 2013 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to the energy labelling of space heaters, combination heaters, packages of space heater, temperature control and solar device and packages of combination heater, temperature control and solar device.
- Commission Delegated Regulation (EU) No 812/2013 of 18 February 2013 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to the energy labelling of water heaters, hot water storage tanks and packages of water heater and solar device.
- Commission Regulation (EU) No 813/2013 of 2 August 2013, implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for space heaters and combination heaters (Text with EEA relevance)
- Commission Delegated Regulation (EU) No 814/2013 of 2 August 2013, implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for water heaters and hot water storage tanks

In addition, a number of mandatory and voluntary instruments at the EU level as of 2016 exist, which regulate the water performance requirements for certain Water-using Products (WuPs) and are the following:

Mandatory

- Council Directive 92/75/EEC of 22 September 1992 on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances: This Directive stipulates the energy labelling requirements of residential washing machines and dishwashers.
- Ecodesign Directive 2005/32/EC: It establishes a framework for the setting of Ecodesign requirements for energy energy-using products.
- Extension of the Ecodesign Directive to include energy-related products: At the end of March 2009, the European parliament and EU governments reached an agreement on proposals to extend the Ecodesign Directive to energy-related products, including WuPs such as taps and showerheads. The logic behind this is that less hot water spent by a shower or tap would also imply less energy needed to heat it, which would reduce total final energy consumption in the EU. Reducing water use would also lead to the reduction of environmental impacts of water supply. WuPs such as showers, taps, washing machines and dishwashers all offer households possibilities for water saving, equally diminishing the energy required to heat the water.

Voluntary

- **European labelling of water-using appliances:** The scheme was designed to promote products that have a reduced impact on the environment compared to otherwise similar ones and to provide consumers with accurate scientifically based information and guidance.

The EU Eco-label has established water consumption criteria for different appliances including dishwashers (Decision of 28 August 2001) establishing the environmental criteria for the award of the Community Eco-label to dishwashers (2001/689/EC)) and of washing machines (Commission Decision of 17 December 1999) establishing the environmental criteria for the award of the Community Eco-label to washing machines (2000/45/EC)). Water performance standards under the EU Eco-label scheme for washing machines and dishwashers use the same requirements that are specified under the Council Directive 92/75/EEC that was discussed in the section on mandatory measures at the EU level. It should be noted that Eco-label criteria for dishwashers and washing machines have expired since 30 November 2008 and 28 February 2009 respectively. These criteria will be reviewed to determine whether they will change and whether these products will stay under the Eco-label scheme

1.4.2 Standards applicable to water-energy efficient buildings

The new set of Energy Performance of Buildings standards, developed by the European Committee for Standardization (CEN) under mandate M/480, provides a methodology to calculate overall the energy performance of buildings, supporting the EPBD. These standards provide EU Member States with a toolbox to help the implementation of the Directive and aim also at higher transparency regarding the energy performance calculation methodologies. Each EPB standard has a template for a national annex that enables Member States to tailor the methodology to the national situation.

The module "M1, Overarching EPB standards" comprises the EPB standards and accompanying technical reports that deal with the overall energy performance of the building. The overarching EPB standards provide basic information needed in the standards covered by the other modules (M2 through M11), such as common terms and symbols or common choice of climatic conditions. And/or they provide procedures how to combine information from these other modules to aggregate into the overall energy performance data, such as the overall primary energy performance.

1. Overarching

Sub-Modules	M1 Module
General	EN ISO 52000-1
Common terms and definitions, symbols, units and subscripts	EN ISO 52000-1
Applications	EN ISO 52000-1
Ways to Express Energy Performance	EN ISO 52003-1
Building Functions and Building Boundaries	EN ISO 52000-1
Building Occupancy and Operating Conditions	EN 16798-1, ISO 17772-1
Aggregation of Energy Services and Energy Carriers	EN ISO 52000-1
Building Zoning	EN ISO 52000-1
Calculated Energy Performance	EN ISO 52000-1
Measured Energy Performance	EN ISO 52000-1
Ways to express Indoor Comfort	EN 16798-1, ISO 17772-1
External Environment Conditions	EN ISO 52010-1
Economic Calculation	EN 15459-1

2. Building as such

Sub-Modules	M2 Module
Building Energy Needs	EN ISO 52016-1, EN ISO 52017-1
(Free) Indoor Conditions without Systems	EN ISO 52016-1, EN ISO 52017-1
Ways to Express Energy Performance	EN ISO 52018-1
Heat Transfer by Transmission	EN ISO 10077-1, EN ISO 10077-2, EN ISO 10211, EN ISO 12631, EN ISO 13370, EN ISO 13789, EN ISO 14683, EN ISO 6946
Heat Transfer by Distribution & Control Infiltration and Ventilation	EN ISO 13789
Internal Heat Gains	EN 16798-1, ISO 17772-1
Solar Heat Gains	EN ISO 52022-1, EN ISO 52022-3
Building Dynamics (thermal mass)	EN ISO 13786

3. Technical Building Systems (under EPBD)

Sub-Modules	**M3** Heating	**M4** Coolling	**M5** Ventilation	**M6** Humidification	**M7** Dehumidification	**M8** Domestic Hot Water	**M9** Lighting	**M10** Building Autom. & Controls	**M11** PV, Wind
General	EN 15316-1	EN ISO 16798-9	EN 16798-3	EN 16798-3	EN 16798-3	EN 15316-1	EN 15193-1	EN 15232-1	
Needs						EN 12831-3	EN 15193-1		
Maximum Load and Power	EN ISO 52016-1 EN 12831-1	EN ISO 52016-1		EN ISO 52016-1	EN ISO 52016-1	EN 12831-3			

Ways to Express Energy Performance	EN 15316-1	EN ISO 16798-9	EN 16798-3	EN 16798-3	EN 16798-3	EN 15316-1	EN 15193-1	EN 15232-1	
Emission & Control	EN 15316-2 EN 15500-1 EN 12098-1 EN 12098-3 EN 12098-5	EN 15316-2 EN 15500-1	EN 16798-7 EN 15500-1	EN 16798-5-1 EN 16798-5-2	EN 16798-5-1 EN 16798-5-2			EN 15232-1	
Distribution & Control	EN 15316-3 EN 12098-1 EN 12098-3 EN 12098-5	EN 15316-3	EN 16798-5-1EN 16798-5-2			EN 15316-3		EN 15232-1	
Storage & Control	EN 15316-5 EN 12098-1 EN 12098-3 EN 12098-5	EN 16798-15				EN 15316-5 EN 15316-4-3		EN 15232-1	
Generation & Control	EN 12098-1 EN 12098-3 EN 12098-5 EN 15316-4-1 EN 15316-4-2 EN 15316-4-3 EN 15316-4-4 EN 15316-4-5 EN 15316-4-8	EN 16798-13 EN 15316-4-2 EN 15316-4-5	EN 16798-5-1 EN 16798-5-2	EN 16798-5-1 EN 16798-5-2	EN 16798-5-1 EN 16798-5-2	EN 15316-4-1 EN 15316-4-2 EN 15316-4-3 EN 15316-4-4 EN 15316-4-5		EN 15232-1	EN 15316-4-3 EN 15316-4-4 EN 15316-4-5 EN 15316-4-10
Load Dispatching & Operating Conditions	EN 15316-1	EN ISO 16798-9						EN 15232-1	
Measured Energy Performance	EN 15378-3					EN 15378-3	EN 15193-1	EN 15232-1	
Inspection	EN 15378-1	EN 16798-17	EN 16798-17	EN 16798-17	EN 16798-17	EN 15378-1	EN 15193-1	EN 16946-1	
BMS								EN 16947-1	

Unit 2: Selection of suitable components and materials and description of their correct positioning in the circuit

Introduction / General description

In the second Unit of Module 1, the trainees will be taught the principles of providing a list of the suitable materials and components and a description of their correct positioning in the circuit in order to improve their knowledge of:

- the adequate selection and positioning of the different elements in the water energy-efficient system,
- the functioning of fittings and other parts of the water-energy efficient system,

Scope – Expected results

With the completion of this Unit, the trainees will be able to:

- identify the correct material and components for the system, and interpret its related available manuals), considering water-energy efficiency requirements and the environment conditions (e.g. climate, orientation),
- describe materials and components functioning position in the circuit,
- limit obstructions and improve the piping network layout, in respect of reducing pipes lengths,
- apply life-cycle considerations when selecting materials,
- provide an estimation of the work to be carried out for the installation of the suitable materials and components.

Key words / basic terminology

Materials for pipes and fittings, pipes diameters, equipment and construction techniques, insulating materials, elements, construction plans, tools, network components.

2.1 Components selection in a water-energy efficient system

A water-energy efficient system shall be designed to strive to achieve the highest level of quality and engineering. Water conservation is a requirement of all plumbing systems. The work performed must comply with the relevant codes and utility requirements. All plumbing engineering drawings are to be coordinated with all disciplines; domestic water, sanitary and storm drainage, and other liquid conveyance systems shall be designed to avoid inappropriate juxtaposition with other utilities. The services of specialty sub-consultants shall be made available when required by the nature of the work.

2.1.1 Plumbing fixtures

All the plumbing fixture accessibility clearances, installation, and accessories must be compliant with the currently applicable existing codes and other relevant Acts requirements. Furthermore, they shall be water-conserving/saving-type fixtures, faucets, and valves. Preferably, what should be provided is Low flow water fixtures, as those described below.

Water Closets (Toilets) - Flushometer Valve Type: the water closets may be either dual-flush or low-flow type, manually controlled or motion sensor controlled. In the US, for example, effective flush volume shall be in accordance with ASME A112.19.14 and EPA WaterSense labeled toilet tank-type High Efficiency Toilet (HET) Specification. For single flush, maximum flush volume: 1.28 gal. For dual-flush – light flush: 1.1 gpf, standard flush: 1.6 gpf.

High Efficiency Toilets (HET) Water Closets - Tank-Type: Tank-type water closets in USA have to comply with the performance criteria of US EPA WaterSense tank-type High Efficiency Toilet specification 1.28 gal.

High Efficiency Urinals (HEU): Urinals must be low-flow, flush-type fixtures. In the US, the maximum flush volume shall be in accordance with ASME A112.19.2 – 0.125 gal.

Public Lavatory Faucets: metered-type faucets for lavatories shall be used. Maximum water use in USA shall be 0.25 gal. per metering cycle when tested in accordance with ASME A112.18.1.

2.1.2 Distribution network

The *domestic cold water service* must consist of a pressurized piping distribution system incorporating an independent (separate) service pipe from the tap at the exterior utility service water main to the water meter and backflow preventer equipment inside the building. The internal distribution must consist of a piping system that supplies domestic potable cold water to all plumbing fixtures, plumbing equipment, water heaters, mechanical makeup, and cold water equipment / system demands.

The distribution of *domestic water service pressure* has to be sufficient in order to provide the outlet pressures required by fixtures or equipment at the hydraulically most demanding (generally the topmost/highest and most remote) outlet. The required outlet pressure must be determined as the minimum requirements of the respective applicable Code or by the higher requirements of the fixture or equipment, as required by the manufacturer. Furthermore, the distribution water pressures must not exceed the system material, piping, and device-rated maximum working pressures, or maximum pressure at the fixture, equipment, or outlet, as required by the Code.

Pressure regulating valves or valve stations where pressures at maximum working pressures may exceed the code maximum must be scheduled and specified.

2.1.3 Domestic water supply equipment and components

As far as the *domestic water supply equipment and components* are concerned, these must include, but not be limited to, the following equipment: water meters, water heaters, water filtration, water softening, pressure booster systems, pressure regulating valves, circulating pumps, backflow preventers, circuit setters/balancing valves, thermostatic mixing valves, expansion tanks, isolation valves, hangers and supports, and thermal insulation.

For example, in the USA the water heaters and expansion tanks must be compliant with ASME standards and with Code, stamped and rated. In the EU, the corresponding standards issued by the European Committee for Standardization (CEN) as well as all Regulations issued regarding the energy labelling and eco-design requirements of space heaters, combination heaters, water heaters, hot water storage tanks, etc. are applied.

Water hammer arrestors must be provided at each elevation change of every horizontal branch to fixture batteries, at all quick-closing automatic valves (mechanical makeup, drinking fountains, flush valves, single lever control faucets, temperature regulating valves, dishwashers, return pumps, and similar), and at each floor on each horizontal main for branches with/without individual fixture or battery water hammer arrestors, for both hot and cold water. Water hammer arrestors in USA must be compliant with the Plumbing and Drainage Institute (PDI) Standard PDI-WH201, ANSI/ ASME A112.26.1M, as required by the corresponding Code, and as recommended/required by the fixture and equipment manufacturer or warranty.

At last, the domestic cold and hot water distribution systems must be insulated: all piping exposed in plenums, or above the ceiling, must be insulated to prevent condensation. It is important to mention that, the thermal pipe insulation for plumbing systems must comply with fire and smoke-developed index in accordance with the corresponding applicable Code requirements.

It is of a critical importance to be able to recognize and decide about which type of piping, as well as water supply equipment and components, to use in a specific application, since this can help preserve the life of a system or avoid a catastrophic failure.

Functioning of fittings and other parts of the system

A fitting is used in pipe systems to connect straight pipe sections, adapt to different sizes or shapes and for other purposes, such as regulating (or measuring) fluid flow. Pipe fittings (especially uncommon types) – see Figure 2.1 for a variety of fittings types - require money, time, materials and tools to install, and are an important part of piping and plumbing systems. Valves are technically fittings, but are usually discussed separately.

Figure 2.1: Various fittings applied in hydraulic installations

[Source: https://www.quora.com/What-are-different-types-of-pipe-fittings]

The purposes of the fittings, shown in Figure 2.1 may be generally stated as follows:

- **Elbows –** used to change the direction of flow between two pipes. Elbows are generally available with an angle of 22.5°, 45° and 90°. If pipes are of same diameter then normal elbows are used otherwise reducer elbows are used. Elbows are made of different materials. These are generally coming with female threads and can be fixed by butt or socket welding also.
- **Nipples –** for making close connections. They are threaded on both ends with the close nipple threaded for its entire length.
- **Couplings –** used to interface the pipes of same distance across. Couplings are additionally valuable if the pipe is broken or spillage happens. For the most part there are two types of couplings are accessible: *pressure coupling* and *slip coupling*. *Pressure coupling* is consistent coupling which is associated between two pipes and it forestalls spillage by the course of action of gaskets or elastic seals on the two sides, generally stick is given. *Slip coupling* is less demanding to install and it contains two pipes which are organized as one into other, inner pipe can slide up to some length.
- **Unions –** a type of fitting, which works as like coupling. In any case, coupling can't be expelled subsequent to fixing however for this situation the union may be evacuated at whatever point this is required. Unions comprises nut, male and female finished strings. Thus, this is additionally valuable for maintaining reason for pipe.
- **Tees and Crosses –** for making branch line connections at 90º.
- **Y-bends –** for making branch line connections at 45º.
- **Return Bends –** for reversing direction of a pipe run.
- **Plugs and Caps –** for closing off open pipe ends or fittings.

- **Bushings** – for connecting pipes of different sizes. The male end fits into a coupling and the smaller pipe is then screwed into the female end. The smaller connection may be tapped eccentrically to permit free drainage of water.
- **Reducers –** they reduce the flow size from larger to smaller by reducing size of pipe. Usually two types of reducers are available: a) the concentric reducer which is like cone shaped with gradual decreasing around the pipe but in this case accumulation of air may possible and it results in cavitation and b) the eccentric reducer which is having one edge parallel to connecting pipe due to which air accumulation is not possible.

2.1.4 Life-cycle considerations when selecting materials, equipment and construction techniques

The choice of materials for a construction project requires considerations of aesthetic appeal and initial and ongoing costs, life cycle assessment considerations (such as material performance, availability and impact on the environment) and the ability to reuse, recycle or dispose of the material at the end of its life.

Materials must be used sustainably – this means the present use will not compromise future use by running out or harming the environment at any time. Few materials fully meet this criterion. The aim when selecting materials should therefore be to use:

- materials from renewable or replaceable sources
- recycled materials
- materials that are in plentiful supply
- materials with a lower environmental impact across their whole life cycle.

Life cycle assessment considerations include:

1. Extraction and manufacture
2. Sourcing
3. Construction/installation
4. Performance
5. Waste disposal/recycling/reuse

Extraction and manufacture

Impact of extraction: The environmental impact of extraction such as large-scale mining, on scarce, non-renewable resources is obvious, but even the extraction of renewable resources will have some impact on the environment. The effects of extraction may be:

- ✓ noise
- ✓ visual pollution
- ✓ air pollution
- ✓ water pollution
- ✓ chemical emission
- ✓ release of CO_2
- ✓ damage to ecosystems
- ✓ water & energy use.

Energy and resource use: The total energy used in the extraction, production, transportation and construction of a building material is the embodied energy of that material. As high consumers of energy, buildings have a significant impact on the environment. Understanding embodied energy allows us to understand how much and where energy is used in the construction of buildings and the benefits of recycling.

By-products and emissions: The processes for the production of building materials can cause pollution and emissions of CO_2 and other greenhouse gases.

Sourcing

Material sources: The source of materials must be considered to keep transport costs and resultant emissions to the minimum. The heavier or more bulky materials are, the greater the transport costs will be. Where possible, heavy and bulky materials in particular should be sourced locally.

Availability: Availability may influence material selection decisions. Long delivery lead-in times must be allowed for as delays may cause project hold-ups and cost and energy losses.

Cost: Cost considerations must include the initial cost of purchase and the life cycle costs of materials. Life cycle costs include those related to the maintenance, replacement, demolition and disposal of the materials. Maintenance cost considerations must also factor in additional environmental costs such as the emission of volatile organic compounds (VOCs) when repainting.

Transport to site: The further materials must be transported, the greater the financial and emissions costs will be. Heavy or bulky products will have greater transport costs than lighter weight materials.

Construction/installation

Health and safety during construction/installation: Some materials such as solvents and chemicals release VOCs, and materials that release dust and other airborne pollutants may be harmful to people during installation or application. Limit harmful effects by:

- using paints, adhesives and primers that contain fewer harmful solvents,
- providing good ventilation in spaces where LOSP treated timber is being used,
- following the recommendations made by the manufacturer or supplier regarding installation or application.

Ease of construction / installation: Materials and systems for ease of construction and installation should be selected. Complicated installations with close tolerances can result in greater wastage or even rework being required.

Adaptability: The design of any building and the materials selection should consider the future use or reuse of the building and use materials that facilitate adaptation or future replacement. The more adaptable a material, the less waste will result from changing needs or tastes.

Performance

Health and safety during the life of the building: Some materials give off emissions or allow run-off or leaching of chemicals that can be harmful to the health of building occupants. Adequate ventilation can mitigate some of the effects of gas emissions, but materials should generally be selected to minimize adverse effects to occupants.

Structural capability: Materials must be selected or designed for their ability to support the loads imposed by the building over the whole life of the building. An appropriate structural system and correct selection of structural materials can reduce excess material use and waste and increase the building's adaptability for other uses.

Durability and maintenance: The available in each country Building Code (also building control or building regulations, being a set of rules that specify the standards for constructed objects such as buildings and non-building structures) sets minimum required levels of durability for different building elements; this will be a primary driver for materials selection. Beyond this, durability and maintenance requirements should be considered together across the expected service life of the building. Some materials that do not appear to offer high levels of durability may actually perform well over many decades with the right maintenance. Timber weatherboards are a good example: where painted every 8–10 years, they can perform well for 60 years or more. Materials that require little maintenance are not necessarily a better choice from an environmental point of view, particularly if their manufacture involves the release of large quantities of greenhouse gases. Materials that require more maintenance may turn out to be preferable if their original manufacture produced very few greenhouse gases.

Moisture resistance: Selected materials must be protected from moisture. Some materials have a natural moisture resistance while others must be fully protected from moisture.

Material deterioration/decay: Some materials deteriorate rapidly, particularly in a moist environment or if they are continuously wet, generally due to the growth of moulds or fungi, or corrosion of some materials, so it is essential that materials selected have the durability required for their area of use.

Thermal performance: Building design and material selection must contribute to good thermal performance and reduced energy demand by including insulation and thermal mass in the building.

Sound insulation: Building design and material selection must contribute to the sound insulation of the building, both from exterior noise and sound transmission within the building.

Fire performance: Building design and material selection must be in accordance with the requirements of the implemented Building Code Protection clauses from fire including fire compartment separations, allowing the occupants safe escape from the building and allowing fire service personnel safe access to the building. Materials must be selected for ignitability, surface spread of flame, fire loading, and fire resistance and stability.

Waste disposal/recycling and reuse

Reuse: Materials that can be reused after the useful life of the building will reduce the need for new materials to be produced in the future. How materials are installed and fixed can have an effect on the ability to reuse them, so the shorter the expected life of the building, the greater should be the reliance on screw or bolt fixing rather than adhesive and other permanent fixings.

Recycling: Materials that can be recycled will reduce the need for new materials to be produced, and the energy required to reconstitute materials is generally much less than required for new production.

Waste disposal: Building design and site management should aim to minimize waste, thereby reducing waste disposal and the release of pollutants. The impact of the disposal of materials at the end of their serviceable life must be considered.

2.2 Positioning of the different elements/components in a water-energy efficient system

2.2.1 Defining the position of the different elements in a water-energy efficient system

A water-energy efficient system must be able of delivering the required each time quantity of water, achieving the appropriate pressure and flow values, meeting in parallel the need for an adequate quality (minimization of the risk of contamination) and assuring the suitable temperature for the carried water. It must be further noticed that, a well-designed and installed system will also be durable, shall minimise noise from water flow and from problems such as water hammer, and support efficient use of water.

A water supply system uses a combination of pipes (varying as far as dimensions and materials are concerned), valves and outlets to deliver water to the occupants of a dwelling and/or building. Some water supply systems may also use storage tanks and pumps. Thus, it is clear that the designing process of a water supply system involves getting all of these elements right so that clean water is delivered to the user at the appropriate rate and temperature. In this context, the following elements are going to be addressed in more detail here: water pressure, water flow rate, flow rate and pipe size acceptable solutions, system layout, backflow, and mains connection (connection to the mains supply).

Water pressure

The parameter of the water pressure is one of the most crucial ones as far as the efficiency as well as the easiness of a water system is concerned: for example, in case that the water pressure is too low, this might prove inconvenient for the building occupants, because there is not adequate flow, while a pressure higher than the one needed could lead to waste of water, as well as more rapid system deterioration. Mains pressure systems require pressure limiting and pressure reducing valves to control water pressure and temperature. Typically, pressure limiting or pressure reducing valves will be used to control pressure in mains-supplied hot water systems or where high pressure may lead to problems such as burst pipes.

Low pressure systems require few valves or controls. In low or unequal pressure systems, pressure can be increased to adequate levels by storing water in a header tank (typically in the ceiling space) so that gravity can be used to create water pressure. Pressure can also be raised to adequate levels using a pressurising pump, in which case it may be necessary to use pressure limiting and pressure reducing valves (the recommended water pressure values, for noise comfort and pipe deterioration issues, are in the range of 150– 300 kPa).

Water flow rate

The Building Codes require that sanitary fixtures and appliances possess an adequate water supply at an adequate flow rate. Attention shall be paid to the issue of the flow rate as well, since a flow rate of a high value may result in water being wasted, whereas a flow rate that is too low will mean that sanitary fixtures and appliances don't work properly. The flow rate is affected by the water pressure, the pipe diameters (the smaller the internal diameter of the pipe, the lower the pressure and flow rate will be) and the water temperature (higher temperatures tend to raise pressure and flow rates).

Limiting the flow for a tap or appliance to adequate rate helps balance the available pressure throughout the system. Regulating flow allows a simpler design and minimum pipe sizes as peak flow rates can be specified accurately and can also reduce noise, splashing taps, and water hammering. Manufacturers' recommendations must be referred to pressure and flow information when selecting tempering valves and outlets (taps, mixers and shower heads). Flow rate can also be controlled by specifying low-flow outlets.

Flow rate and pipe size acceptable solutions

Outflow rates and pipe sizes should be set. When calculating pipe sizes, the speed of the water (velocity) moving through the pipes must not exceed the value of 3.0 m/s (target calculated values of 0.5 m/s – 2.0 m/s are recommended).

System layout

During the design process, the layout of a plumbing system shall largely follow room layout. Nonetheless, there are many things to consider which relate to Code compliance, building users' comfort, and sustainability. While elaborating the planning of a water supply layout, the following preconditions have to be considered:

- ✓ *Pipe runs and lengths*: the pipe runs must be kept as short as possible, while the pipes must pass close to fixtures in order to the number of branches and unnecessary elbows, tees and joints to be minimized. In case that longer pipe runs and more fixtures exist, this will lead to a reduced flow rate, increased heat losses, but also to increased use of materials.
- ✓ *Point of entry into the building*: this point should be located into a utility space such as garage / laundry and include an accessible isolating valve, line strainer and pressure limiting valve (if required so).
- ✓ The *water heating system* must be centrally located to contribute to the reduction of the length of pipe runs to fixtures because the longer pipe runs require more water to be drawn off before hot water is discharged. A separate point-of-use water heater for fixtures that are more than 10 m from the main water heater is suggested to be installed.
- ✓ *Noise prevention*: the pipes shouldn't run over or near bedrooms and living areas.

Backflow

Backflow is the unplanned reversal of flow of water (or water and contaminants) into the water supply system. The system must be designed and used to prevent contamination from backflow, which is particularly important in recycled water systems.

Mains connection

Where the water source is a mains supply, the network utility operator is responsible for the water supplied to the property boundary. The property owner is then responsible for providing the pipework to bring the water into the building. An isolating valve must be fitted at the point of connection to allow for maintenance and repair of the building's water supply system if required.

2.2.2 Preparation of the necessary construction plans

The preparation of the plumbing drawing is a very demanding and detailed procedure that has to be followed. The water supply system (i.e. the system layout and pipework) must be designed in order to assure an appropriate water pressure and flow, and to avoid potable water contamination. In addition, a water system must be suitable for the temperature of the water carried.

A well-designed and installed system will also be durable, minimise noise from water flow and from problems such as water hammer, and support efficient use of water. A typical water supply system uses a combination of pipes (of different dimensions and materials), valves and outlets to deliver water to the users / occupants of a building. Some water supply systems also use storage tanks and pumps. The designing of a water supply system involves getting all of these elements right so that clean water is delivered to the user at the appropriate rate and temperature.

Below some specific guidelines are provided as to how to proceed with the preparation of the necessary construction plans (drawings):

- ✓ The hot-water-demand requirements have to be evaluated. The water heater, the mixing valve, and the circulation pump should be selected and sized. The hot-water system needs to be provided with a circulating return unless the distance between the heater and the farthest fixture is relatively short.
- ✓ The combustion air requirements for atmospheric gas-fi red water heaters have to be determined.
- ✓ The selection of pipe material for each part of the plumbing system from supply systems to drain systems must be reviewed, while purity requirements, corrosion issues, fluid temperature, fluid pressure, joining methods, hanger spacing, code issues, and physical protection also have to be taken into consideration.
- ✓ Provide pipe-expansion loops or expansion joints where required.
- ✓ Provide valves on distribution branches, on branches off supply risers, and at the base of supply risers. Provide drain valves with hose threads at the base of risers and in the low portions of piping.
- ✓ Provide hose bibs around the building. Select frost-proof hose bibs if required. Review landscape irrigation connection point where required.
- ✓ Coordinate structural penetrations and housekeeping pads with the architect and structural engineer. Review weight of water heater and other equipment with the structural engineer.
- ✓ Select fixtures and fixture trim, including faucets, shut-off valves, flush valves, carriers, strainers, drains, traps, and wall flanges. Send fixture cut sheets to the architect. Include dimensioned drawings of fixtures and fixture trim.

- ✓ Select sprinkler-head designs including escutcheons or covers, finish type or colour. Send sprinkler-head cut sheets to the architect.
- ✓ Select size and design of floor drains and receptors to meet requirements. If required, segregate clear-water wastes from sanitary wastes. Connect clear-water system to the storm-drain system.
- ✓ Provide cross-connection control for potable water supply connections to building equipment and systems, for all fixtures, and for accessories as required. In particular, provide air gaps or approved backflow preventers for connections to boilers and to sprinkler supplies. Provide air gaps for relief ports of backflow preventers, for pressure-relief valves, and generally for fixture faucet outlets.

2.3 Methods and tools for the selection and positioning of the components in the network

There exists a number of relevant tools that can be of use by an engineer during the process of the selection and positioning of the most appropriate components in a hydraulic network. For example, the **Building Information Modeling (BIM)** is paving the way to more effective multi-disciplinary collaborations with a total lifecycle and supply chain integration perspective. BIM is the process of generating and managing data and information about built environment during its entire life cycle from concept design to decommissioning (Figure 2.2).

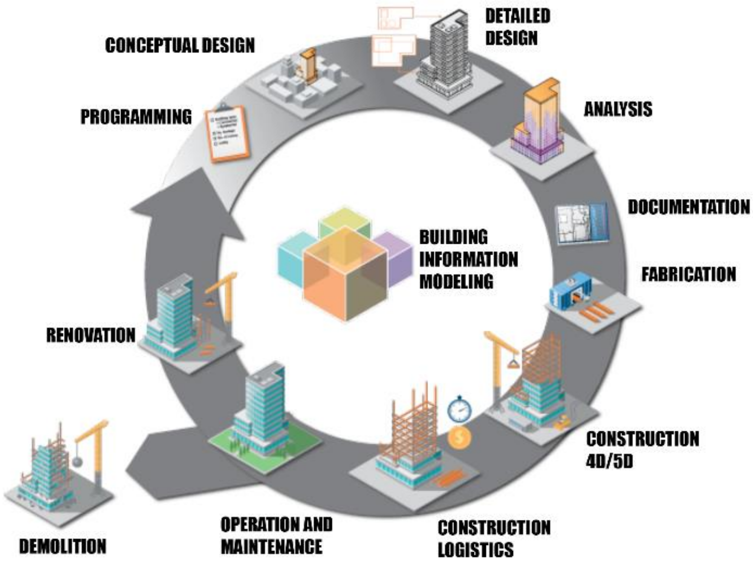


Figure 2.2: BIM uses across building lifecycle

[Source: Optimizing Energy Efficiency in Operating Built Environment Assets through Building Information Modeling: A Case Study, by I. Petri, S. Kubicki, Y. Rezgui, A. Guerriero, H. Li]

BIM brought the most transformative power into AEC/FM domain (Architecture, Engineering and Construction/Facility Management) during the last decade in terms of its fundamental life cycle and supply chain integration and digital collaboration. BIM holds the critical key to revolutionize the construction industry, while it is helping the sustainability agenda as the digitalisation of product and process information provides a unique opportunity to optimise energy efficiency related decisions across the entire lifecycle and supply chain.

There are several areas that are key to the potential growth of BIM for energy and water efficiency and its impact on the green building marketplace:

- Multi-disciplinary integrative capacity of BIM: it provides a unique opportunity to integrate data, information and underpinning processes across lifecycle and supply chains. This will promote informed and energy efficient design interventions.
- Informed sustainability design: it contributes to sustainable lifecycle decisions and processes as it leverages on the capability of the complete construction value chain thus optimizing design decisions on complex issues such as energy efficiency.
- Modelling standards: it is currently promoting the development and adoption of a wide range of standards and best practice guide as evidenced by BIM adoption dynamics in the UK.
- Increase of BIM use for retrofit: there is an increasing trend for use of BIM in large as well as smaller projects with a sought benefit of maximizing energy efficiency and sustainable outcomes. Recognition of the appropriateness of BIM for small retrofit projects is also critical given the dynamic growth anticipated in the green retrofit market in the existing domestic stock across Europe.
- Using BIM for building performance monitoring: there is an increasing evidence of the value BIM tools during the operations and maintenance phase of a project, with the view of reducing the endemic gap between predicated and actual energy consumption in buildings.
- Training support & communication tool: As BIM embraces building products and processes, it constitutes a useful support for training, and to communicate the best practices for energy efficient and high quality construction, in particular to on site staff.

More specifically, while used in plumbing projects, this methodology may create deeper project knowledge, deliver a more robust product, while it can also contribute to the reduction of the total costs of the entire water- energy efficient project. However, to the best of the authors' knowledge, the BIM software has not yet been extensively used in cold water hydraulic networks, including all water use points (e.g., toilet, shower, etc.).

Another recently elaborated relevant tool is the **Revit**. This is a collaborative tool, while its use typically requires more team coordination in comparison to typical projects with the use of the well-known and frequently used **AutoCAD**, and this should be reflected in project planning and cost estimating for design. On a Revit project, getting consultants on board and involved earlier in the project, potentially in the concepts or schematics phase instead of the design-development phase, should lead to a better coordinated finished model, resulting in fewer problems during construction.

The design of a plumbing installation may prove to be a little more complicated with the use of Revit, in comparison to other design processes, such as HVAC or electrical design, since in the former case the software has to take into account sloped piping, sanitary drain vent, storm drain lines, and so many other more complex parameters and fittings/fixtures. In the most recent version of Revit the ability to design sloped piping is quite improved, though it can be time consuming if someone needs to connect multiple sloped pipes together and retain the slope with the correct fittings.

The plumbing design also requires lots of piping in small spaces. In addition, plumbing design in AutoCAD is typically schematic in nature, so it requires a shift in mind-set for designers to start thinking of their components as real-life objects and how they will be installed during construction. The use of Revit in plumbing design is actually more complicated in comparison to its use in HVAC or electrical design, since in the former case it deals with sloped piping, a sanitary drain vent, storm drain lines, etc. Nevertheless, the expert intending to use it, may take advantage of some advice on common situations that a typical plumbing designer may face in Revit that are provided on related blogs created for this purpose.

Some of the benefits that Autodesk Revit offers are:

- ✓ It creates an opportunity for the designer to better understand the design.
- ✓ It delivers a single model with dynamic views that can be customized to show specific components. The sections can be cut and displayed quickly for any area as a result of the comprehensive information available in the model.
- ✓ It offers the designers the possibility to make a change in one place and have that change automatically and immediately replicated in every place it should occur throughout the model.
- ✓ It offers the capability to pull data like fixture units and flow for sizing.
- ✓ It provides the ability to set up typical design and document schedules that can rapidly increase documentation time.
- ✓ It offers designers the functionality to create Groups of typical connections that can be designed and copied to other floors, as well as to reuse data-rich plumbing families that can cut future families development time.
- ✓ It delivers a higher level of model detail when using manufacturer-specific fittings and accessories.
- ✓ It offers systems data that provides in-depth detail of pipe length and fitting sizes for crucial mechanical equipment selections for hospitals and labs.
- ✓ It supports working in a collaborative model that forces interdisciplinary coordination, which ultimately produces a better product for the owner.

Unit 3: Control and monitoring equipment, positioning in the circuit and main operating parameters

Introduction / General description

In the 3rd Unit of Module 1 the ways of providing clear indications of control and monitoring equipment, its main operating parameters and its correct positioning in the circuit will be showcased to the participants in order to improve their knowledge of:

- the adequate control and monitoring equipment for the water energy-efficient system,
- the correct position in the circuit of the adequate control and monitoring equipment for the water energy-efficient system,
- the functioning parameters of the adequate control and monitoring equipment for the water energy-efficient system.

Scope – Expected results

After having finalized this LU, the trainees will be able to:

- identify the adequate control and monitoring equipment for the water-energy efficient system and interpret its related manuals, considering water-energy efficiency requirements and environmental conditions (e.g. climate, orientation),
- describe control and monitoring equipment functioning,
- correctly position in the circuit the adequate control and monitoring equipment.

Key words / basic terminology

Control and monitoring equipment, water flow metering, circuit, smart meters.

3.1 Control and monitoring equipment applied to water energy-efficient systems

3.1.1 Introduction to water flow metering

Water (smart) metering in buildings provides information to the user in terms of the water quantity their building consumes. The user is then likely to become more engaged in monitoring its water use, leading to more efficient water use, but also more active involvement in the identification of leaks.

The metering of water use is in place in many EU Member States (such as Denmark, France, Greece, Spain, Portugal, and Belgium) but is inconsistently applied (e.g. hot water metering for each dwelling and cold water metering for the whole building). Water metering is reported to be also strongly linked to water pricing discussions in Austria, Bulgaria, Belgium, Estonia, Spain, the Netherlands, Sweden and the UK, or that are still under development (Cyprus, Czech Republic, Ireland, Romania, and Slovakia). Water-metering may face technical constraints as individual dwellings and related piping may not allow the installation of individual meters at suitable points of entry.

Generally speaking, the benefits of metering are that:

- it allows water metering instead of water consumption estimation;
- in conjunction with volumetric pricing, it provides an incentive for water conservation;
- it helps to manage water consumption areas in the distribution network, thus providing a basis for reducing the amount of non-revenue water;
- it is a precondition for quantity-targeting of water subsidies.

However, as already mentioned above, there is disagreement as to the effect of metering and water pricing on water consumption. The price elasticity of metered water demand varies greatly depending on local conditions. The effect of volumetric water pricing on consumption tends to be higher if the water bill represents a significant portion of household expenditures.

There is evidence from the UK that there is an instant drop in consumption of some 10% when meters are installed, although in most instances consumption is not directly measured prior to meter installation, so the benefits are uncertain. Whilst metered water users in the UK do use less than unmetered users, in most areas metering is not compulsory, so the metered customers are a self-selecting group. Another example is Hamburg, Germany, where domestic water consumption for metered flats (112 litre/capita/day) was 18% lower than for unmetered flats (137 litre/capita/day) in 1992 [Water Performance of Buildings, Final Report, EU, DG Environment, August 2012].

The implementation of smart water meters, which collect real-time water use information, is also shown to help users address their water uses and help water businesses manage their network more efficiently, by detecting leakages or any other abnormal use efficiently (from the EC public consultation on water efficiency in buildings, 6% of respondents currently use smart water-meters). Given the related costs, the implementation of smart-metering could be restricted to water-stressed areas, as pinpointed by several stakeholders.

3.1.2 Types and functioning of water flow metering devices and their positioning in the circuit

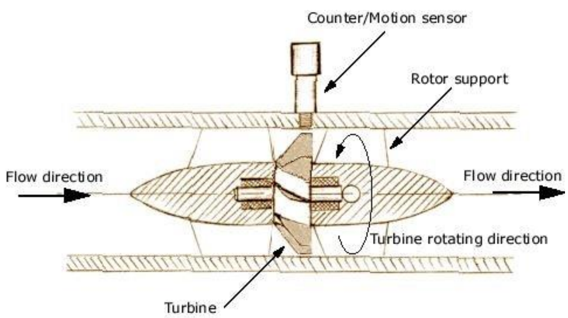
A water flow meter is an instrument capable of measuring the amount of water passing through a pipe. Several water flow meter technologies are available for selection depending on the water measurement applications, budgetary terms, and maintenance requirements. Each of these water flow meter types has a unique principle of operation, overall cost-of-ownership, and specific application benefits.

There are two common approaches to flow measurement, displacement and velocity, each making use of a variety of technologies. Common displacement designs include oscillating piston and nutating disc meters. Velocity-based designs include single- and multi-jet meters and turbine meters. There are also non-mechanical designs, for example, electromagnetic and ultrasonic meters, and meters designed for special uses.

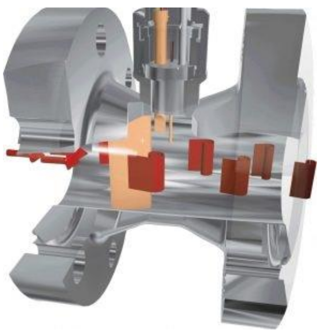
Most meters in a typical water distribution system are designed to measure cold potable water only. Specialty hot water meters are designed with materials that can withstand higher temperatures. Meters for reclaimed water have special lavender register covers to signify that the water should not be used for drinking.

The question is what water flow meter should users select for their water flow measurement application? There are four main (common) types of water flow meters: mechanical (also called turbine) water flow meters, ultrasonic flow meters, vortex volumetric flow meters, and/or magnetic flow meters.

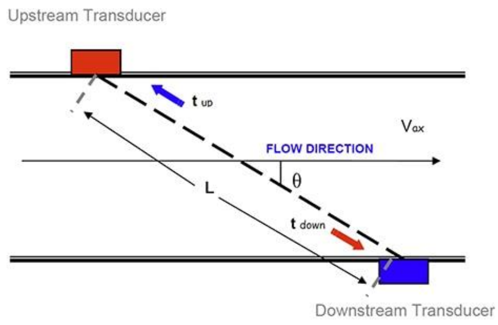
Mechanical flow meters are the most common and economical type of water flow meters which perform flow measurement through turbine rotation with a shunt, propeller, or paddle wheel design. The mechanical types of water flow meters work by measuring the speed of water flowing through the pipe that causes a piston or turbine to rotate. The volumetric flow rate of the water is proportional to the rotational speed of the blades. The disadvantage of mechanical water flow meters for water measurement is that they may clog up when the water is dirty or contain larger particles, which leads to increased maintenance costs. Mechanical water meters also do not work well when the water flow is low.



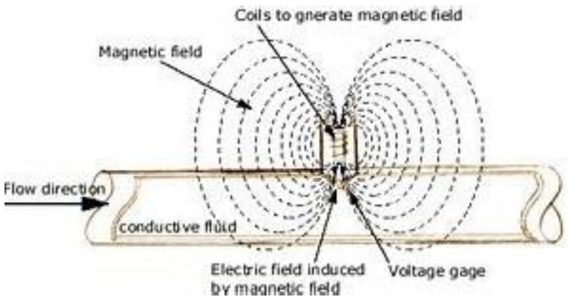
Vortex flow meters use vortices shed from a sensor immersed in the flow. Vortices are forces of nature, "swirls" produced when a fluid moves past an obstruction, like the wind past a flagpole or water flowing around a rock in a stream. In a vortex meter, a sensor tab flexes from side to side when each vortex flows past, creating a frequency output that is directly proportional to the volumetric flow rate. Multivariable vortex flow meters can measure up to five process variables with one process connection: temperature, pressure, density, mass flow, volumetric flow rate. Insertion vortex meters work well on very large pipes as they can be inserted into the flow by hot tapping with a retractor.



Ultrasonic flow meters measure the speed of fluid passing through the pipe using ultrasound to measure the volumetric flow. In a transit-time ultrasonic liquid flow meter, an ultrasonic signal is transmitted in the direction of the flowing fluid downstream, and then another signal is transmitted against the flowing fluid upstream. In its most basic form, the time for the sonic pulse to travel downstream is compared to the time for the pulse to travel upstream. Using this differential time, the velocity of the following fluid is calculated. Then the meter calculates the volumetric flow rate in the pipe using this fluid velocity. In addition, BTU energy measurement can be derived from the volumetric flow rate and the temperature difference between the hot and cold legs. Clamp-on ultrasonic meters can measure water from outside of the pipe by shooting pulses of sound through the pipe walls, thus having application flexibility and making them suitable for water flow measurements in large pipes.



Magnetic flow meters measure the speed of a fluid passing through a pipe using a magnetic field to measure the volumetric flow. They are based on the principle of Faraday's Law of Electromagnetic Induction, according to which liquid generates voltage when it flows through a magnetic field. The more rapid the fluid flow, the more the voltage generated. The voltage produced is directly proportional to the water movement; the voltage signal is processed into the volumetric flow rate by the electronics. Since the magnetic flow meters show an intermediate accuracy, they are not suitable for custody transfer applications and cannot be used to measure pure water as there are no ions to measure.



The ideal water flow meter type is determined by the details of the application, as some flow meters work better than others in certain situations. Water flow meters are generally owned, read and maintained by a public water provider such as a city, rural or private water company. In some cases an owner of a mobile home park, apartment complex or commercial building may be billed by a utility based on the reading of one meter, with the costs shared among the tenants based on some sort of key (size of flat, number of inhabitants or by separately tracking the water consumption of each unit in what is called sub-metering).

3.2 Smart water meters as an integral part of an automated water supply system

As mentioned above, historically, the principal use for meter data is customer billing, with billing as the main driver for meter installation, followed by water conservation. As such, meter readings were only required when a new bill needed to be generated. This low data requirement has meant that many meters are still manually read and only infrequently (often only once a year). A "smart" water meter has the ability to store and transmit a large amount of data that are related to the consumption and the use of water in real time. It is an electromagnetic water meter that is battery powered and which can measure the water flows for many years gathering continuous online information on water consumption.

The advantage of an electromagnetic meter is that there is no loss of pressure inside the water meter and maintenance can be limited. A separate battery supplies electrical power for the wireless system and this enables the user to read the water meter at a distance. The smart water meters are equipped with a chip so that the water consumption is immediately registered through a tele-metering system to the portable devices/appliances of the end users and /or to the data base of the water supply companies. The water meters besides the water volume (water consumption) do also register the time and way (i.e. final use) of consumption.

The smart water meters make part (i.e., are an integral part) of an automated water supply system or, else, of an advanced metering infrastructure (AMI). These systems provide the possibility of measuring and further analysing information relevant to water consumption and then communicate this information to the consumer / client through the internet. The water supply companies are using the automated water supply systems as part of a wider development initiative called “Smart Grids”, also including electricity and natural gas services (consumption measuring).

The AMI technology is a broadening of the already existing advanced measurement reading (AMR). AMR is facilitated by the meters having the capability to send out a data signal, which can be picked up by a meter reader, facilitating passive reading, through drive-by or walk-by. AMI differs by providing a two-way communication and allows the sending of information and commands to the final users for multiple purposes (e.g. use in real time and pricing information, leakage detection or any other improper use identification, exchange of messages on targeted efficient use, measuring changes in water use and even services of distant termination of supply).

The revealed information has the ability to assist in the building operational management as identifying leaks and excessive water consumption. Some of these diagnostic analyses are "low hanging fruits", where a low-cost or no-cost corrective measure yields great water savings and at the same time achieves an efficient control of the building. Data could also be applied to empower the end users. By information and feedback on consumption, improved customer service as well as transparency is achieved, which possibly could lead to positive behavioural change. Daily, weekly and monthly consumption could be presented to the customer as well as social comparisons and alerts for leaks or high consumption.

A goal of processing end user consumption data is to create a better decision basis. By utilizing smart meter data as input and transforming these data through different and purpose dependent analyses, generated outputs are potentially actionable insights to support decisions. Data driven decisions have recognized benefits and pose an efficient tool for improved water management.

Unit 4: Considerations regarding maintenance and troubleshooting works most likely to occur in a water-energy system

Introduction / General description

In the 4th Unit of Module 1 of the WEEs course, the ways to indicate (to the customer) the maintenance, repair and replacement (if necessary) works - including the relevant costs for them - most likely to occur in the water-energy efficient system will be provided to the trainees in order to improve their knowledge about the entire maintenance procedure that the water-energy systems need to follow. Thus, the different kinds (categories and subcategories) of a typical maintenance procedure are further analysed, while the topic of the preparation of a maintenance plan is also addressed.

Scope – Expected results

Following this training unit, the trainees will be able to enhance their ability:

- on how to prepare a suitable maintenance plan for the water–energy efficient system each time under consideration;
- to implement in practice the methods for proper maintenance, repair and replacement of the water-energy system components.to provide an estimation of the work to be carried out for the system maintenance and troubleshooting throughout the building life-cycle.

Key words / basic terminology

Maintenance plan, scheduled maintenance, preventive maintenance, corrective maintenance, improvement maintenance, predictive maintenance, unscheduled maintenance.

4.1 Maintenance works of water-energy systems

4.1.1 Introduction

Maintenance has been more popular in principle than in practice over the years. Maintenance is defined as the combination of all technical and administrative actions including supervision actions intended to retain an item, or restore it, in a state in which it can perform a required function. Thus, the maintenance is a set of organized activities that are carried out in order to keep an item in its best operational condition, with the minimum cost acquired.

Maintenance is of much importance in today's world. The idea of keeping equipment well maintained to extend its expected life and to avoid future repair cost is often misunderstood. The issue of the maintenance is of much importance in the implementation of projects in today's industries. Maintenance is carried on energy systems in order for them to keep their performance within acceptable standards and to maintain their average life expectancy.

The cost associated with maintenance work is largely dependent on how often maintenance routines are carried out and on the extent that work that is done. Life cycle costs (LCC) of both dynamic and static (assets) of water-energy systems are greatly influenced by the maintenance activities performed on them during their life cycle. The relationship between the cost of maintenance and returns such projects can be expected to deliver is sometimes unclear.

The objectives of the procedure of maintenance include:

- ✓ Reducing breakdown and emergency shutdowns.
- ✓ Reduction of down time.
- ✓ Minimizing the energy usage.
- ✓ Optimizing Resources utilization.
- ✓ Improving equipment efficiency
- ✓ Optimizing the lifecycle of the equipment
- ✓ Providing reliable cost and budgetary control
- ✓ Identifying and implementing cost reductions

Maintenance of water-energy systems can be divided into the two maintenance actions:

- ✓ Scheduled maintenance.
- ✓ Unscheduled maintenance.

4.1.2 Scheduled maintenance

The energy system manufacturer determines the initial maintenance requirements through the Operation and Maintenance (O&M) Handbook. The requirements are initially treated as mandatory. However there comes a variation to the tasks or task scheduled as experience is developed within the operational environment. The costs of performing the tasks, manpower material costs, as well as the costs of any extra work arising from the scheduled task are also considered.

In Figure 4.1 below, the major tasks performed under scheduled maintenance are presented. The Scheduled Maintenance can be further distinguished into:

- Preventive maintenance;
- Corrective maintenance;
- Improvement maintenance;
- Predictive maintenance.

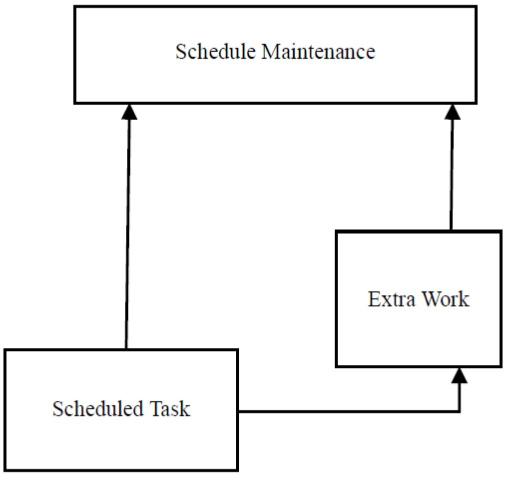


Figure 4.1: Major components of scheduled tasks

[Source: Ref. [13]]

<u>Preventive Maintenance</u>

This is the type of maintenance carried out before failures occur. This can be subdivided into *scheduled* and *condition based* preventive maintenance.

Scheduled preventive maintenance in energy systems includes replacements, adjustments, major overhauls, inspections and lubrications, adjustment or calibrations, cleaning and replacement of certain components [14].

Preventive Maintenance may in its turn also be subdivided into:

- Routine maintenance;
- Running maintenance;
- Opportunity maintenance;
- Window maintenance;
- Shutdown preventive maintenance.

All these depend on the manufacturer guideline, the availability of the machine as not to halt the process of production (machine is working or not) and cost of maintaining the system/machine at that particular period [13].

<u>Corrective Maintenance</u>

Corrective maintenance is subdivided into:

- *Remedial Maintenance*: These are activities performed to eliminate the source of system failure without altering the continuity of the production process.
- *Deferral Maintenance*: These are corrective maintenance activities that are not immediately initiated after the occurrence of a failure, but delayed in such a way that will not affect the process of production line [14].

Corrective maintenance includes the following steps:

1. Fault detection.
2. Fault isolation.
3. Fault elimination and verification of fault elimination.

In fault elimination, however, several steps are taken in order that fault eliminations can be carried out effectively. These include:

✓ Identification of incipient problems;
✓ Proper repair procedures;
✓ Effective planning (depends on the skills of planner, availability of well-developed maintenance database about standard time to repair, complete repair procedures, required labour skills, specific tools, parts and equipment);
✓ Verification of repair;
✓ Adequate time to repair.

Improvement Maintenance

This is always used in reducing the need or to completely eliminate the need for maintenance. Improvement maintenance could be in the form of:

- Design-out Maintenance: These are set of improved maintenance activities used to eliminate the cause of maintenances, reduce maintenance tasks and to increase the performances of machines/ systems by redesigning those parts of the machine vulnerable to frequent occurrence of failures.
- Engineering Services: This includes construction modifications, installations and rearrangement of facilities.
- Shutdown Improvement Maintenance: Here, the production processes are put on hold, to perform some improvement maintenance activities on the system.

Predictive Maintenance

Predictive maintenances are set of activities performed on a system to detect the physical condition of the equipment in order to carry out the appropriate maintenance works to maximizing the life span of the equipment without increasing the risk of failure [14].

Predictive maintenance is subdivided into two categories:

1. *Condition-based predictive maintenance*. This type of maintenance schedule specifies maintenance tasks as they are required by the system involved. It depends on the continuous and periodic condition monitoring of the equipment to detect any sign of failure.
2. *Statistical-based predictive maintenance*. This depends on the information and statistical data

gathered as a result of the careful and cautious recording of the stoppages of parts of the system and its components, in order to develop models for predicting failures.

The main advantage of predictive maintenance is the early discovery of faults and failures, due to continuous monitoring of the system. However, its main setback is that it depends solely on the information gathered over a period of time, and the correct interpretation of this information. It is sometimes classified as a form of preventive maintenance.

4.1.3 Unscheduled maintenance

The unscheduled maintenance has to do with unplanned maintenance works, carried out on energy systems in the case of emergency or breakdowns. The cost of a system failure includes the cost of repair, the deferral cost of that repair (if applicable) and the cost of operational disruption as a result of the failure. Figure 4.2 shows the major components of the unscheduled maintenance.

Repair Cost

Repair costs include manpower required to remove the associated components as well as shipping, administration and shop repair costs [13]. Repairs may be performed on energy systems in which case, the manpower and materials will contribute to the costs.

Deferral Cost

Sometimes it will be acceptable with some of the system inoperative. Details of these systems are usually given in the manufacturer handbook. Costs of deferral accounts for the resources required to take the action detailed, and must also account for operational restrictions due to in-operative systems.

Operational Disruption Cost

Operational disruption cost can vary significantly in the type of system involved, production process involved and the location where the system is situated.

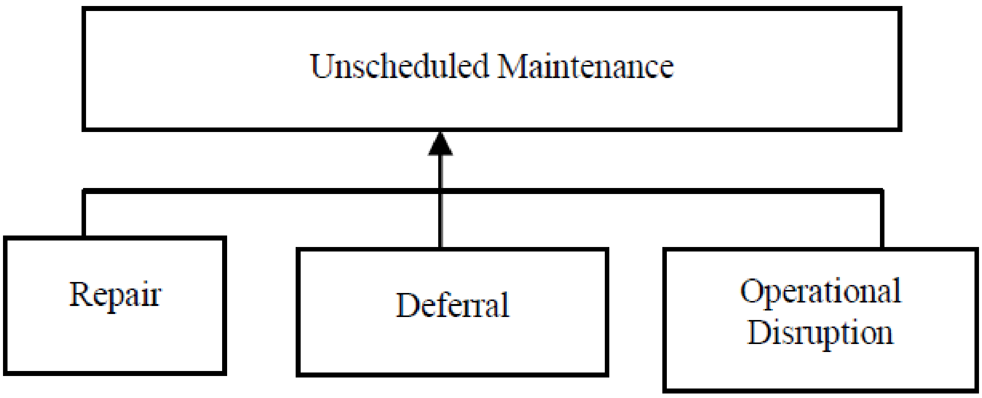


Figure 4.2: Major components of unscheduled tasks

[Source: Ref. [14]]

4.2 Preparing a maintenance plan for a water-energy system

The elaboration of a maintenance plan is of critical importance, in view of an energy system, for all the reasons explained and analysed in the former sections. The effect of maintenance on (water) energy systems cannot be underestimated. It has valuable effects on the life cycle cost of a system and as well as on the energy utilization with improvement on the life span of the system itself.

Results that have been provided by various researches on this issue have shown that maintenance has a way of improving the ROI of the amount invested in installing and building of a system (e.g. especially the HVAC system very frequently used in residential houses). It is ideal that more preventive maintenance should be carried out on the HVAC as compared to the corrective maintenances. Finally, following a strict and comprehensive maintenance schedule will prolong a building's HVAC systems, save cost of replacements, reduce the loss of energy and increase the comfort of building occupants.

The steps and format of preparing a maintenance plan will vary depending on the application and design of maintenance systems. The key steps in preparing a typical maintenance plan will include the following:

1) Prepare an asset inventory;
2) Identify maintenance activity and tasks;
3) Identify the frequency of the task;
4) Develop an annual work schedule;
5) Prepare and issue a work order.

The planning of an effective maintenance is essential to the overall maintenance environment. The maintenance plan's contents, which include the actual work, instructions, schedule, workers, spare parts, and contractors, guide all the maintenance work activities.

A maintenance plan eventually consists of a document that defines the work needed to be done to maintain assets in a facility proactively. The contents of the document help the energy expert facilitate the continued use of an asset at optimum performance. This way, significant breakdowns or unforeseen renewal may be avoided, as long as an effective maintenance plan is drawn at the beginning. The idea behind maintenance planning is to ensure that the proper working condition of the water-energy system is assured.

An effective plan needs to cover all the features of the system's maintenance policy. Thus, it should contain an exhaustive inventory of assets that the expert needs to maintain (e.g. a list including numerous items like boilers, pumps and other hydraulic system's components). Of course, the specific maintenance tasks that must be performed need to also be identified. It is suggested that in cases this is possible, these tasks shall be aligned to individual assets. A reasonable maintenance schedule should also suffice in guiding the whole maintenance program.

In the following paragraphs, some of the most crucial points/issues that need to be planned during the elaboration of a maintenance plan are briefly analysed:

The work

All the work that needs to be done has to be clarified defining exactly what has to be done, during the creation of a maintenance plan; the priority areas as well as the sequence of activities once the maintenance work begins must be decided.

Instructions

Proper instructions limit the dependency on specific workers. The maintenance work also needs to meet particular quality standards and such standards may be achieved with the inclusion of explicit instructions in the plan. Furthermore, during the preparation of the plan, the person responsible for it may consider including job observations that can performed to guarantee the efficiency of the maintenance tasks.

Schedule

The purpose of the schedule is to do the work as often as needed – not over-maintaining by doing the work too often – not under-maintaining so that downtime and breakdowns are experienced. It is always wise to set aside the maintenance window when a new year begins. It shall be ensured that production is well aware of this window. As the year wears on, the designer may need to proceed with making necessary changes to the plan to increase its efficiency.

Workers

The plan has to indicate the appropriate skill set for each maintenance task. This information will inform the choice of the best contractors for the work. Depending on the organizational arrangements, each member of the maintenance team has to be assigned to specific areas.

Spare parts

In this phase, the spare part consumption can be predicted. Once the parts that will be needed are indicated, the worker knows exactly what to pick from the store – before he goes to do the actual maintenance work. With this section, the maintenance manager gets insight into parts used in the previous period as well as future part consumption. They'll have an easier time preparing a budget for the next twelve months.

Contractors

Some maintenance tasks may require outside contractors. They include external specialists who come on-site to do specialist work. Most of them bring special equipment like mobile cranes and metering equipment tools to service assets. The effective maintenance plan specifies the work that contractors are requested to do. With this section, it is not necessary to count on one specific contractor for all maintenance tasks. These specifications could be used to request quotes and tenders from different contractors to do a particular type of work.

Unit 5: Designing of efficient systems for green areas and landscapes

Introduction / General description

In the 5th Unit of Module 1 of the WEE Course the principles for designing of water-energy efficient systems for green areas and landscapes are presented. The general principles and considerations together with the green areas and landscapes design and maintenance strategies are further analysed. In addition, the most adequate green areas and landscapes considering efficiency criteria (e.g. autochthonous / native and low-water use plants) and the environment (e.g. irrigation programs) and surrounding conditions (e.g. lower runoff) are described. At last the present unit contains information about the topic of the green areas and landscapes design steps.

Scope – Expected results

At the end of this Unit, the trainees will be able to:

- correctly design and maintain building green areas and landscapes,
- apply water-energy efficiency techniques and/or methods in landscape design.

Key words / basic terminology

Green areas, landscapes, design principles, hydrozoning, irrigation systems, outdoor water efficiency, design.

5.1 Green areas and landscapes design principles and considerations

The design of a water-energy efficient system targeted for green areas and landscapes includes the selection of the suitable plants (on a regional level), the efficient design, the proper treatment of potential slopes, mulching, and efficient measures for pools, spas and other water features, in case these are installed. In the case that not any permanent landscapes can be installed in view of the climate conditions or because occupancy of units in multi-family buildings precedes the installation of common-area landscapes, then the alternative of the installation of temporary landscapes (e.g., straw over bare soil) may be followed instead.

It is suggested that the landscape designer selects native or climate appropriate plantings. The best practice is to choose certain species of plantings that are appropriate for the specific features of the examined site, taking into consideration that there may be the case where that different parts of the same site may vary significantly as far as the soil type, exposure to sun, wind, and associated evaporation rates and moisture levels are concerned.

The procedure of the smart planting takes into consideration both local and microclimate conditions. A microclimate is defined as a small location that has environmental conditions which are not typical to those characterising the rest of the wider area. For example, a certain microclimate might exist near a large rock. As the sun heats the rock, the rock will give off heat. Thus the environment around the rock will be warmer than the area at a 3 m distance from the rock. In addition, the shade produced from a tree might also be considered as a microclimate as well, since it is generally noticed that the temperature under the tree differs from the one further away from the tree.

Another important approach is the fact that some drought-tolerant plants, particularly in dry regions, are able to significantly reduce the demand for water, chemicals, and maintenance. In some climates, it is even possible to eliminate the need for permanent irrigation through the use of drought-tolerant plants and improved landscape design. Drought-tolerant plants vary by region, and the landscape designers should consult local or other resources to choose the most appropriate local plants. Slow-growing perennials and shrubs are often some good potential candidates.

A healthy soil can effectively cycle the nutrients, minimize runoff and maximize the water holding capacity, absorb excess nutrients, sediments, and pollutants and provide a healthy rooting environment and habitat for plants. Some practices that allow soils to function as a base for large, healthy plants that require fewer pesticides, fertilizers, and supplemental water for plant growth are to preserve the existing topsoil, to add organic material, and to minimize the compaction. Healthy soils also maintain a permeable soil structure, which ensures higher water infiltration rates that in turn reduce erosion, runoff, and flooding potential.

5.1.1 Landscape design

Many terms and schools of thought have been used to describe approaches to water-efficient landscaping. Some examples include “water-wise,” “water-smart,” “low-water,” and “natural landscaping”. While each one of these terms varies in philosophy and approach, they are all based on the same principles and are commonly used interchangeably. One of the first conceptual approaches developed to formalize these principles is known as “Xeriscape landscaping.”

Xeriscape landscaping is defined as "*quality landscaping that conserves water and protects the environment*". The word "Xeriscape" was coined and copyrighted by Denver Water Department in 1981 to help make water conserving landscaping an easily recognized concept. The word is a combination of the Greek word "xeros," (meaning "dry") and the term "landscape." The seven principles upon which "Xeriscape landscaping" is based are:

- ✓ Proper planning and design
- ✓ Soil analysis and improvement
- ✓ Appropriate plant selection
- ✓ Practical turf areas
- ✓ Efficient irrigation
- ✓ Use of mulches
- ✓ Appropriate maintenance.

Additionally, the eight fundamentals of water-wise landscaping, below, illustrate the similarities in the underlying concepts and principles of Xeriscape landscaping and other water-efficient approaches.

- ✓ Group plants according to their water needs.
- ✓ Use native and low-water-use plants.
- ✓ Limit turf areas to those needed for practical uses.
- ✓ Use efficient irrigation systems.
- ✓ Schedule irrigation wisely.
- ✓ Make sure soil is healthy.
- ✓ Remember to mulch.
- ✓ Provide regular maintenance.

Thus, in case the owner / user manages to maintain the landscape implementing the above described principles of water efficiency, it shall continue to both conserve water and remain attractive

Water-efficient landscapes are designed in a way that will minimize the need for supplemental water. It is a fact that turfgrass is frequently over-watered by homeowners who do not understand its water requirements. A water-efficient landscape consists of a variety of medium or low water using plants in combination with functional turfgrass areas.

Limiting turfgrass to areas where it aesthetically highlights the house or where it has a practical function, such as in play areas, can increase the water efficiency of the yard while still providing benefits to the homeowner. Some communities have prescriptive requirements that limit the coverage of turfgrass as a means to address their local water supply challenges.

During the design of a landscape area, the designer must take into consideration the local climate while selecting the plants and then proceed with categorizing those to various group plants (each characterised by similar water needs), a practice known as "hydrozoning" (grouping plants together based on similar water requirements), as is shown in Figure 5.1. For example, the drought-tolerant plants, as sages or cacti, should not be planted in a bluegrass lawn; on the contrary, they should be separated, since bluegrass is characterized by a much higher water requirement. Furthermore, the sensitive plants would be best positioned in the shade, whereas plants that can tolerate more heat and/or wind might be better of positioned by the road.

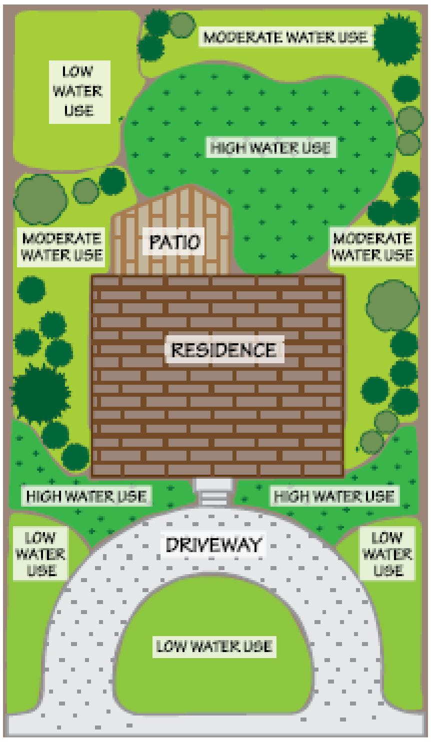


Figure 5.1: Hydrozoning

[Source: *Resource Manual for Building WaterSense Labeled New Homes.* U.S. EPA (2012)]

The procedure of hydrozoning is also very useful for taking advantage of the microclimates. The kinds of plants that can tolerate more heat and wind are always suggested to be planted near the streets, while the more sensitive plants might be planted in shade, under roof overhangs, or in fenced areas, so as to remain more protected. The hydrozoning can also refer to a design practice undertaken to improve the efficiency of the irrigation. The system is designed so that plants with similar watering requirements are watered together and separated from plants with different requirements. For example, one group of plants might need watering for 20 minutes, while another group of plants may need only 10 minutes. Similarly, one group might require year-round watering, while another might require it for only a small portion of the year.

Steep slopes in landscapes provide a challenge for the landscape design because of their potential for erosion and runoff from stormwater and irrigation water. Erosion can be a serious problem if vegetation is not established. Care should be taken to ensure that appropriate plantings are used and that only irrigation methods suitable for slopes are applied. South-facing slopes can warm up and dry out quicker than other areas, while north-facing slopes can be cooler than surrounding areas.

Considerations must be given to the plantings installed on slopes, as it may not be safe to operate a lawn mower on slopes greater than 2:1 (2 m of horizontal run per 1 m vertical rise). Trees and shrubs create a tight network of roots and stems that not only bind soil particles together, but also act to slow the force of rushing water down the hillside. Turfgrass on steep slopes can help to bind the soil with roots, but might not slow down stormwater runoff. Thus, heavy rains can wash away turf, roots and all. Taller growing grasses, wildflowers, shrubs, and trees do a much better job of slowing stormwater runoff from steep slopes.

Terracing is an alternative approach to planting on slopes. Open terraces can be dug into the slope in the shapes of steps. The existing slope can be cut, and the excavated soil can be used as fill. A low soil berm (ridge) can be formed at the front edge of each step or terrace to slow the flow of water.

Mulching is an extremely important practice for establishing plantings, as it helps to conserve moisture in the root ball of the new plant until it establishes roots in the adjacent landscape soil. Mulch also helps discourage weeds that can compete with new plantings for water, nutrients, and light. Mulch can be used instead of grass around individual trees and shrubs in a lawn. This greatly reduces the competition for water and nutrients from the turf and increases the growth rate and health of trees and shrubs.

In addition to being useful around plants, mulch can be used as a groundcover for walks, trails, driveways, and natural and play areas. It can be used temporarily to cover low-growing tender plants to protect them from frost injury. Mulch also can be composted and used as a soil amendment. For trees, at a minimum, mulch should be applied to the area below the tree's canopy from the tree base to the drip line, or the border of the canopy of the tree, leaving space between the beginning of the mulch layer and the tree trunk to prevent rot.

Too much mulch, however, can create problems. Because mulch helps retain moisture, too much mulch can lead to excess moisture. Especially in trees, this can lead to root rot. Do not pile mulch against the stems of plants or the trunks of trees, as this can cause stress on the plant tissues and lead to pest problems. Too much mulch can also alter the pH of the soil, causing toxicities or deficiencies. Piled mulch provides a home for rodents, which in turn may chew the plant roots and cause tree girdling. Fine mulch can become matted if applied too thick, preventing air and moisture penetration.

5.1.2 Irrigation systems

Good irrigation design and scheduling provide one of the greatest opportunities for water – thus, energy too - efficiency in the landscape. The goal of a good irrigation system design and layout is to develop a system with good overall distribution uniformity to maintain plant health while conserving water resources. It is important to have these systems installed by specialized irrigation partners that have a specified level of expertise and have passed a comprehensive exam covering general irrigation subjects, as well as specialty areas including water efficiency.

Using common watering practices, a large portion of the used water applied to lawns and gardens is not absorbed by the plants themselves. On the contrary, it is lost through the well-known procedures of evaporation, runoff, or being pushed beyond the root zone because it is either applied too quickly or in excess of the plants' needs. The goal of efficient irrigation is to reduce these losses by applying only as much water as is needed to keep the irrigated plants as healthy as possible.

Even before the irrigation system is used, leaks can occur as a result of improper installation, damage from construction equipment, or weather damage (freezing and thawing). In drip systems, leakage problems might be the result of tubing or tape that has been damaged by foot traffic or gnawing and chewing of animals. Indications of leakage from an irrigation system include overgrown or particularly green areas of turf, soggy areas around spray heads and aboveground hoses, jammed spray heads, and torn hoses.

A significant amount of water is wasted due to runoff and overspray from irrigation systems onto non-landscaped areas. Overspray is the situation where irrigation systems apply water to hardscape such as driveways, sidewalks, and streets. Runoff is the situation where the water runs off the landscape and is not available for use by the plants. This is usually a result of poor scheduling or improper design and/or installation. Thus, systems should be designed and installed to avoid the application of water to impermeable and non-vegetated areas.

Irrigation system components should be selected to avoid runoff. The irrigation designer should select components to keep the sprinkler precipitation rate below the infiltration rate of the soil, and the schedule should use repeat cycles to allow the water to soak into the root zone. In addition, the design should separate zones for sprinklers at the top and bottom of sloped areas, because these areas tend to be the source of runoff. Due to sprinkler head type, spacing, system pressure, and other factors, irrigation systems do not apply water in a perfectly uniform manner. The goal is to have a system that applies water across the landscape as uniformly as possible.

Ensuring a high percentage of distribution uniformity starts with efficient irrigation system design. This includes head-to-head coverage (see Figure 5.1) and proper sprinkler head spacing and location. To achieve head-to-head coverage, sprinkler heads should be separated by a distance of 50% of the spray radius. Because spray uniformity of a single sprinkler decreases further out along the radius of water spray, head-to-head coverage provides a more uniform distribution among the irrigation system as a whole. Sprinkler heads should also be located to avoid overspray onto impermeable surfaces, fences, buildings, and neighbouring property.

Specific devices such as pressure-regulated heads or multi-stream, multi-trajectory rotating nozzles will also increase uniformity. Pressure-regulated heads adjust the flowing water pressure to maintain a constant outlet pressure. Most irrigation systems operate better at a water pressure of 30 psi, but some irrigation systems, such as drip irrigation, require lower pressures. Multi-trajectory nozzles can be used in place of standard nozzles and use a number of individual streams of varying trajectories to achieve a more even distribution.

Irrigation systems are usually set on a timer to start watering regardless of weather conditions, resulting in systems running when it is raining. A rainfall shutoff device interrupts a scheduled irrigation cycle when a certain amount of rainfall has occurred. These devices eliminate unnecessary irrigation, conserving water. Rainfall shutoff devices are relatively low-cost and an essential component of an efficient irrigation system.

Rain sensors are small devices wired to the irrigation system controller and mounted in an open area where they are exposed to rainfall. Rain sensors operate by one of two methods: measuring or weighing collected rainwater using water weight or the electrical conductivity of water or measuring the proportional expansion of water-sensitive materials such as cork disks. Soil moisture sensors allow an irrigation event to occur when the sensors determine that sufficient dryness has occurred in the soil. Conversely, the sensors prevent the system from running where there is sufficient moisture in the soil and irrigation is required.

A very important part of an irrigation system is the controller. It is a tool to apply water in the necessary quantity and at the right time to sustain landscapes and to achieve high levels of efficiency in water, energy, and chemical use. Irrigation controllers have been available for many years in the form of mechanical and electromechanical irrigation timers. These devices have evolved into more sophisticated computer-based systems that allow accurate control of water, energy, and chemicals while responding to environmental changes.

A sensor-based controller uses real-time measurements of one or more local factors including temperature, rainfall, humidity, solar radiation, and soil moisture. A sensor-based system often has historic weather information (i.e., an evapotranspiration [ET] curve) for the site location programmed into memory, then uses the sensor information to modify the expected irrigation requirement for the day. A signal-based controller receives a regular signal of prevailing weather conditions via radio, telephone, cable, cellular, Web, or pager technology. The signal typically comes from a local weather station and updates the current ET rate to the controller on a regular interval.

Different landscape types can be watered most efficiently with different types of irrigation equipment. Sprinkler irrigation is best suited to water maintained turfgrass, as it can be designed to distribute water evenly over uniform turfgrass areas. Shrubs, trees, plant beds, and any other non-turf landscape can be watered most effectively using micro-irrigation. Micro-irrigation supplies water directly to plant roots and eliminates overspray and runoff. The varied heights of shrubs, trees, and plant beds can obstruct spray from sprinkler heads.

Sprinkler heads shall have a 10 cm or greater pop-up height, as they need a certain amount of clearance over the turfgrass surface to operate correctly. Over time, as the turfgrass grows, it can build up around sprinkler heads, interfering with the spray pattern. Because taller risers are above the turfgrass, they can distribute water more evenly.

Designing a system with matched precipitation nozzles is an important water-efficiency concept. A sprinkler head’s precipitation rate is the speed at which water is applied to a specific area. When an installer designs an irrigation system for a landscape, sprinkler heads are installed to deliver enough water to cover the entire area of the landscape. When all of the sprinkler heads within the zone/system have the same (or very similar) precipitation rates, they are said to have “matched precipitation.” Designing a system with matched precipitation rate heads/nozzles can save water by ensuring that all areas of the landscape are watered at the same rate. This is especially important when a landscape has sprinklers with varying coverage (for example, half-arc and quarter-arc sprinklers).

Sprinkler irrigation should not be used on strips less than 1.2 meters wide, because it is difficult to irrigate narrow strips efficiently without creating overspray. Sprinkler irrigation should not be installed on slopes in excess of 4 m of horizontal run per 1 m vertical rise (4:1), because the flow rates associated with sprinklers are often a source of runoff on steep slopes.

The term "micro-irrigation" describes a family of irrigation systems that apply water through small devices and at lower pressure than sprinkler irrigation systems. These devices deliver water onto the soil surface very near the plant or below the soil surface directly into the plant root zone. Compared to sprinkler irrigation systems, the conveyance loss is minimal and evaporation, runoff, and deep percolation are reduced. Because micro-irrigation operates at a lower pressure, a pressure regulator is required. Filters are required because emission devices are easily clogged by debris. Flush end assemblies flush the laterals after the end of an irrigation cycle.

One of the single most important aspects of efficient irrigation is proper scheduling of the system. Plant water needs change with **plant maturity**, **seasons**, **climate**, and **day-to-day weather**. The type of soil also plays a role in the irrigation schedule, due to varying infiltration rates associated with different soils (e.g. silt, sand, clay). Applying too much water in one irrigation cycle will result in runoff or deep percolation. Not applying enough water per cycle will encourage shallow roots. The biggest problems encountered are watering too much and too frequently. Many of the common turfgrass and landscape shrub diseases are made worse by or are the result of watering too frequently. Homeowners often do not change their irrigation system schedules during the year, which can result in significantly overwatering the landscape for large portions of the year.

In the same context, the "seasonal irrigation" adjustments are of a major importance aspect of the setting of an irrigation system. It is obvious that the grass will most likely require more water during the hot summer months in order to stay green, likewise, during winter and autumn, the plant water demands are reduced accordingly with falling temperature. Thus, the use of "irrigation controllers" that are equipped with features to adjust the irrigation scheduling are recommended to make seasonal adjustments easier.

The "seasonal adjust" feature can also be known by other names such as "water budget". These functions work the same way – by increasing (or decreasing) the set irrigation times. The intention of this feature is that the controller program is set at a baseline level and the seasonal adjust feature is then used in order to increase or decrease the irrigation time depending on the season. For example, if an irrigation zone is set to go on for 10 minutes daily in June-August, if the seasonal adjust is set to 150% for December-February, that zone will now water for 15 minutes daily. If the system does not have a controller, the seasonal adjustment can be made by reducing the time of irrigation during the cooler months of the year.

Another equally important parameter is that both the irrigation system and the emitters that are selected must be appropriate for the "microclimate" of the irrigated area, for the "plant selection" and for the "soil type". The irrigation system should be set up so that it is able of delivering the right amount of water to the right places.

Different methods of irrigation, sprinklers or drippers, may be more appropriate for different parts of the green landscape. In addition, different types of emitters may be more appropriate for different zones of the landscape. There are a wide range of emitters, including drippers, micro-sprayers, pop up and gear drive sprays, and fixed sprinkler heads. Most drippers generally use between 2–8 litres per hour, micro-sprayers between 0.4–2.5 litres per minute, and medium to low sized gear drive or pop-up fixed sprinklers about 6–9 litres per minute.

There are also a range of control devices that can help save water including:

- Tap timers: they allow the user to set the irrigation times.
- Sprinkler controllers: they typically offer the choice of different irrigation programs for different garden zones, which can be altered based on weather, soil moisture or evapotranspiration.
- Rain sensors: they feed back to the controllers in case of rain.
- Soil moisture sensors: they feed back to the controller when the irrigated area has reached adequate moisture levels.

- Evapotranspiration sensors: they enable the controller to adjust the irrigation for that day based on the sunlight and temperature.

5.1.3 Other measures for outdoor water efficiency

A water-efficient landscape begins in the planning stage with all parties involved. There are many additional strategies that can be implemented to go above and beyond the scope of minimizing outdoor water use and maximizing onsite water retention. Certain strategies such as site preparation will require coordination between the builder/developer and landscape professionals.

Install permeable surfaces, rather than impermeable hardscape, where appropriate: Impervious hardscape surfaces such as driveways and sidewalks contribute to storm-water runoff from the site. Storm-water transports pollutants and sediment to nearby water bodies and can lead to erosion downstream. To decrease storm-water runoff, permeable hardscape can be used in place of any impervious hardscape materials or - if unnecessary - removed altogether. This will increase infiltration of water, replenishing aquifers and providing a healthier site for landscape plants.

Where hardscape on the lot is necessary, open pavers or engineered porous materials are a good replacement for impermeable concrete. Permeable pavement options include porous bituminous asphalt, porous concrete, porous paver blocks, and reinforced turf. When considering permeable pavements, builders should be mindful of site constraints and maintenance requirements. One potential site constraint is a shallow water table. Stormwater is cleaned as it percolates through the soil, but a shallow water table may intercept stormwater from permeable pavements before the water is sufficiently cleaned. Additionally, builders should recognize that like all hardscapes, permeable pavements require maintenance.

Preserve or restore proper soil structure, chemistry, and depth prior to installing landscape plants: Soil structure, chemistry, and depth are essential to the survival of landscape plants. In many cases, nutrient-rich topsoil is removed from the site, or soil compaction occurs during construction. Healthy soils support thriving plants and biological communities, as well as provide water storage and infiltration, reducing runoff.

The landscape professional should conduct a thorough analysis of both the physical and chemical characteristics of the soil. Based on this analysis, the professional should prepare the soil according to locally accepted best management practices. This may include the addition of top soil, other soil amendments, tillage, or other strategies to create the appropriate planting medium for landscape plants. Soil amendments and tillage improve soil's capacity to support vegetative growth by increasing soil water-retention capacity, improving infiltration, and enhancing soil fertility.

Minimize site clearing during the construction phase and ensure appropriate site requirements, such as soil depth and proper grading, prior to landscape installation: Conventional construction practices disturb the site by clearing existing vegetation and moving earth, resulting in bare, compacted soil. Compacted soil makes it difficult for water to pass through the soil and reach the roots of the plants. Construction practices increase erosion, inhabitability of the site for new vegetation, and the likelihood of storm-water runoff. A site that is minimally disturbed is preferable, because it has decreased landscape water use, healthier soils, and decreased erosion and runoff.

Builders should make construction crews aware of site preservation and ensure compliance with all local construction codes related to erosion and storm-water control. Consider grading and topsoil installation where appropriate and repair compacted soils prior to landscape installation by tilling or other suitable means.

Water flow in irrigation systems is controlled through the use of *valves*. Valves can be manually or automatically operated and can be used in various irrigation applications to shut off flow completely, reduce flow to a set rate, or regulate water pressure. These functions are accomplished using on/off service valves, control valves, check valves, and pressure-regulating valves. An appropriate valve should be chosen based on the desired valve function. Correct valve sizes should also be chosen to account for pressure loss in the valves. Pressure loss is especially important in automatic valves, which rely on pressure differences to power the system. Builders should refer to manufacturer information on valve models to choose the correct valve.

Last, but not least, and in addition to the measures mentioned above regarding permeable surfaces and site development, installing rain gardens, green roofs, vegetated swales, rain barrels, or cisterns will further decrease the amount of storm-water leaving the site and filter out pollutants before they enter the municipal system or are discharged to surface water.

Another option that should be considered is the use of recycled water for irrigation purposes. Recycled water is the treated wastewater after removing solids and certain impurities. Characteristics of recycled water depend on its source, treatment level and geographic location. Of course, despite the significant benefits of recycled water, there are several concerns related to environmental and health risks. If not properly managed, recycled water could deteriorate soil health in terms of increased salinity and sodicity, heavy metal accumulation and decreased hydraulic conductivity of soil. However, there are tools to reduce these risks.

5.2 Green areas and landscapes design steps

During the design procedure of a green area and/or landscape a set of specific steps has to be followed. First of all, the area that is going to be landscaped has to be precisely calculated. The calculation of the allowable amount of water to be used by the landscape is the next step and this can be elaborated with the use of any of the available calculating tools.

One of the most widely used tools for this purpose is the “WaterSense Water Budget Tool” produced by the US Environmental Protection Agency (EPA), which can be used to ensure a measure of efficiency and regional suitability for the amount of water applied to a landscape based on the local climate data. This budget tool is quite simplified as it involves three main steps on how to proceed with the desired output. A detailed guide on how to use the tool is available in the EPA website. [9]

As a start, basic information has to be collected so that the landscape water allowance is estimated. At this stage, the area of the landscape is determined: for single-family homes, the landscaped area includes the front yard minus any hard-scaped areas (e.g., concrete driveways, walkways, and decks or porches). It includes all areas that are improved upon by features such as turf, water features, irrigation systems, pools or spas, and other permanent vegetation. Areas outside the front yard, which have temporary stabilization measures such as straw or mulch, do not need to be included in this area. Septic drainage fields and public rights-of-way should also be excluded from the landscaped area.

Next, the landscape water requirement (LWR) or how much water the landscape shall need is also calculated. With the completion of this calculation, the tool will automatically estimate the amount of water that the specific landscape shall require during the peak watering month at the specific site, thus determining whether the designed landscape meets EPA’s criteria.

As the water budget is a site-specific method of calculating an allowable amount of water to be used by the landscape, it takes into account the plant type, the plant water needs, the irrigation system design, and applied water that the landscape receives either by irrigation or by precipitation. Water budgets must be associated with a specified amount of time, such as a week, month, or year.

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SELF-ASSESSMENT QUESTIONS FOR MODULE 1

1.	**For the evaluation of the loads of a building, both thermal energy and water demands have to be evaluated. Which of the following statements are correct (T) and which are false (F)?**	
	a. The calculation of the thermal energy demand is performed for the entire building	F
	b. While calculating the thermal losses, the heating state is considered as permanent	T
	c. The cooling tower water use can be estimated based on the cooling capacity	F
	d. The water demand evaluation is based on 3 main steps	T
2.	**Which of the following data must be available for the calculation of the thermal needs of a building?**	
	a. Location plan of the building	√
	b. Floor plans and sections	√
	c. Weather conditions	√
	d. Thermal capacity of the boiler	
3.	**As the water demand increases, the pressure at the hydraulically remote fixture will increase as well. This statement is:**	
	a. Correct	
	b. Wrong	√
4.	**The "elbows" are…. (*complete the phrase*)**	
	a. used to change the direction of the flow between two pipes.	√
	b. used to change the velocity of the flow between tow pipes.	
	c. generally available at angles of 35°, 45° and 90°.	
5.	**The term "micro-irrigation" describes a family of irrigation systems that apply water through small devices and at (*choose the correct answer*)**	
	a. lower pressure than sprinkler irrigation systems….	√
	b. higher pressure than sprinkler irrigation systems….	
6.	**Characterize the following statements as True or False**	
	Most meters in a typical water distribution system are designed to measure cold potable water only	T
	There are three main (common) types of water flow meters	F
	AMI stands for "advanced metering instrument"	F
7.	**In the context of the 5Rs (Which of the following statements are correct (T) and which are false (F)?**:	
	Restore: take resources (other than water) out of wastewater and put them to use.	F
	Recover: return water of a specific quality to where it was taken from	F
8.	**Characterize the following statements as True or False**	
	a. The mechanical flow meter works by measuring the pressure of the water flowing through the pipe.	F
	b. Insertion vortex meters can function well on very large pipes.	T

	c. In ultra-sonic flowmeters the velocity measurement is basically based to the measurement of the distance covered by the fluid.	F
9.	**The Preventive Maintenance …. (*complete the phrase*)**	
	a. belongs to the category of the Scheduled Maintenance.	√
	b. belongs to the category of the Unscheduled Maintenance.	
	c. is an independent maintenance action of energy systems.	
10.	**Characterize the following statements as True or False**	
	a. Sprinkler irrigation is best suited for shrubs, trees, plant beds and any other non-turf landscape.	F
	b. Micro-irrigation operates at lower pressures, so a pressure enhancer is required.	T

MODULE 2: SUPERVISION DURING THE CONSTRUCTION, COMMISSIONING AND OPERATION OF A PROJECT

SUMMARY

The second of the four Water Efficiency Experts (WEE) Modules that the WATTer Skills project has produced is dedicated to the topic of the supervision and the commissioning and more accurately to the entire supervision of an energy-water project starting from the initial phase of the construction, moving to the commissioning and finally to the operational phase of it.

This Module integrates three Units:

Unit 1: Supervision process of the construction works for keeping up the contractual terms of performance

Unit 2: Necessary tests and procedures to secure inspection and commissioning

Unit 3: Supervision and monitoring of operation (Operational Supervision)

In the 1st Unit of Module 2 of the WEE's Handbook, the supervision process during the construction works for keeping up the contractual terms of performance is analytically presented. The roles and the responsibilities of the Site Supervisor (SS), the Qualified Person (QP) and the Contract Administrator (CA) are analysed, while the various steps and phases of the supervision process are also presented. The ways for monitoring whether the selected components and tools meet the project requirements and do comply with building regulations are further provided.

In Unit 2 the focus is set on the supervision during the phase of the (inspection and) commissioning of a water-energy project. More specifically, the commissioning procedure is analytically addressed. The tests and procedures for the testing and commissioning are further and detailed described, focusing on the separate and consecutive steps and phases that have to be followed. Finally, the relevant regulations, guidelines and standards applying to the commissioning of systems are briefly, yet fully, presented.

In the 3rd Unit, the supervision that has to be implemented throughout the final phase of the operation of the project (system) is addressed. The operational supervision is further analysed into the "Condition Monitoring" and the "Condition Based Maintenance" explaining the reasons why these two procedures/strategies are suggested as necessary parts of the entire supervision process.

Unit 1: Supervision process of the construction works for keeping up the contractual terms of performance

General description

In the 1st Unit of Module 2 of the WEE Course, the supervision process during the construction works for keeping up the contractual terms of performance is analytically presented. More specifically a distinction is made between the roles of the Site Supervisor (SS) and the one of the Qualified Person (QP). The roles and the responsibilities of the Contract Administrator (CA) are analysed, while the various steps and phases of the supervision process are also presented. The last topic addressed is the keeping up the contractual terms of performance, presenting the ways for monitoring whether the selected components and tools meet the project requirements and do comply with building regulations, through the supervision process. At last, the most important regulations and standards applicable to a water energy efficient project (before and after commissioning) are provided.

Scope – Expected results

At the end of this Unit, the candidate should be able to:

- efficiently implement the supervision process of the foreseen works and undertake the roles of either the SS or the CA;
- estimate whether the selected components and tools that are used comply with the contractual terms of performance.

Key words / basic terminology

Site Supervisor, Contract Administrator, Qualified Person, components, project requirements, tools, building regulations, standards, responsibilities, contractual terms of performance, construction phases.

1.1 Supervision process

The supervision of construction process is a very important step that follows after the design phase of a water efficient hydraulic system. This in order to ensure that a safe and proper water supply as well as an adequate drainage system are assured for the building's occupants, and that adequate and proper fixtures and equipment complying with national and European standards are installed, to guarantee that no contamination and waste of water will take place, amongst other criteria. In order for a plumbing system to be properly and thoroughly inspected and supervised before commissioning, a major aspect that has to be taken into account is that all the selected components are as a first step properly functioning and as a second step correctly positioned and installed in the hydraulic circuit.

The supervision of each site is planned individually, acknowledging its unique requirements. The entire supervision procedure takes place initially through the necessary worksite inspections and then through the compiling of certain required written documentation. Generally speaking, the **project manager** acts as the head of the project, both directing and supervising its progress in accordance with the goals set and the project contracts. The **site supervisor** ensures that the project is implemented as planned. More specifically, his/her role involves the management and the supervision of a construction site in accordance with health and safety guidelines.

It is the responsibility of the site supervisor (SS) to assess hazards, determine risks, conduct regular inspections, and maintain a safety program. The site supervisor will typically work closely with the site foreman, who is responsible for organizing construction works on site, and report to the project manager. It should be noticed that, depending on the complexity of the building, there can be different specialities needing supervision, from the aspects related with civil works or equipment functioning, to water quality or user safety.

At last, the site supervisor has to regularly report to the qualified person (QP), especially in the case that any irregularities or deviations are noticed. Furthermore, the QP is the one who shall undertake the responsibilities of the site supervisor, in case the latter is not in position of keeping up with the time schedule of planned inspections. In the majority of cases, all these tasks are subcontracted to a sole person, the contract administrator (CA).

1.1.1 Role and responsibilities of the Site Supervisor (SS)

The main responsibilities of a site supervisor typically include:

- **Supervising** workers, subcontractors and work activities and ensuring that the construction works are not deviated from the approved structural plans: it is the statutory role of the SS to ensure that the construction works carried out by the builder do follow strictly the approved structural plans. The SS should report to the QP immediately if the builder proposes to carry out construction works which are deviated from the approved structural plans.
- **Detection of construction irregularities**: The SS should immediately notify the QP and the builder in case that construction irregularities are detected at site, so that any corrective measures can be taken to rectify these, before carrying out on the next stage of construction works at site.
- **Minimization of abortive construction works:** The SS should work closely with the builder and his sub-contractors in carrying out inspections at different stages of the construction. The SS should

regularly check the construction works, and if there are construction irregularities found during the construction, he/she should notify the builder and his sub-contractors to immediately rectify them. Frequent inspections carried out by the SS would minimise any major shortcomings detected during the final inspection prior to concreting of the structural elements.

- **Adhere to site inspection schedule:** The SS must adhere to the site inspection schedule as prepared. In addition, he/she shall notify the QP if he may not be able to carry out site inspection on the scheduled date and time so that alternative arrangement could be made for a replacement SS (e.g. an engineer from the QP's office to carry out the site inspection). The SS has to work closely with the builder to adhere strictly to the site inspection schedule, in order for any disruption to the overall progress of the construction works at site to be avoided.

In a more general context, the site supervisor has to fulfil the following tasks:

- Prepare and present site inductions, safety briefings and toolbox talks.
- Assess and manage safety hazards.
- Ensure appropriate site rules and welfare facilities are in place.
- Carry out regular inspections.
- Help project managers to plan the work programme.
- Help co-ordinate deliveries of materials, plant and equipment.
- Complete records for site reports.
- Attend site management meetings.
- Carry out regular inspections to ensure compliance with relevant legal requirements, processes and procedures.
- Raise safety concerns at the appropriate level.
- Resolve problems and implement improvements.
- Organise and oversee external inspections, such as with a health and safety inspector.
- Provide emergency first aid if required.

Some additional relevant skills of a site supervisor should include:

- ✓ A positive attitude.
- ✓ The ability to communicate with, motivate, and if necessary discipline the workforce.
- ✓ The ability to understand drawings and other contract documents.
- ✓ A good understanding of safety procedures.
- ✓ First aid training.
- ✓ Organisational skills.
- ✓ The ability to mediate to resolve issues.
- ✓ An understanding of legal responsibilities.
- ✓ An understanding of welfare and environmental issues.
- ✓ An understanding of occupational health and behavioural safety issues.

1.1.2 Role and responsibilities of the Qualified Person (QP)

The main responsibilities and foreseen tasks of the qualified person are:

- **Safeguard construction works to meet design specification:** The QP should visit the site frequently to ensure that site construction works are carried out in accordance with the design specification of the building structures, especially during construction of critical structural elements, such as transfer structures, critical joint connections in steel structures, etc.

- **Compliance with the Building Regulations:** It is the statutory role of the QP to ensure that the building works are designed in accordance with the provision of the applicable Building Code. The QP shall also ensure that those building works are being carried out in accordance with the relevant plans approved by the Commissioner of Building Control.
- **Conduct essential tests on building materials:** It may be the case that certain materials, such as steel bars, pre-stressing wires, etc., are imported. Thus, the quality of these materials can vary significantly depending on the technology used and the quality control of the manufacturers. It is therefore important for the QP to require the builder to engage an independent testing agency to conduct tests for the confirmation of the quality of these materials. The QP should also stipulate the number and frequency of such tests to be carried out by the independent testing agency.
- **Implement instrumentation monitoring measures:** The QP should instruct the builder or specialist builder to install site monitoring instruments to measure the effect and performance of the construction works. The instrumentation monitoring results serve as an early alarm if the adjacent building properties are affected or the performance of the construction works cannot meet the design specification. Based on the monitoring results, the QP should immediately stop construction works, and take corrective measures to rectify the shortcomings.
- **Steel frames / precast structures fabricated off site:** For steel frames or precast concrete structures that are fabricated off site, the QP should appoint another SS to supervise the construction of these structures off-site. The QP should brief the SS and the builder to carry out the necessary verification tests on these structures when these structures are delivered to the site. If the tests fail to meet the design specification of the building, the QP should reject the structures delivered at site.

1.1.3 Role and responsibilities of the Contract Administrator (CA)

The role of the contract administrator (CA) is to practically administer the project in such a way that the correct contractual procedures and good administrative practices are being followed, and that the life of the building contract from inception to completion is accurately and completely recorded. When there do not exist any specific procedures, the CA should carefully consider what activities ought to be undertaken and how these are communicated in order to ensure that the project is fairly and effectively administered. The CA should devise and promulgate procedures that will address this.

The CA will also have additional responsibilities to the employer under the CA’s terms of appointment, as he should read the documents to become familiar with their requirements and obligations. The CA should be aware of the actions that are required to be performed by all those affected by the building contract, as well as the time limits for those actions. To achieve this at the time the building contract is formed, the CA should read through the building contract conditions, to become familiar with the requirements and obligations, the specialist sub-contract documents, the specifications of works/bill of quantities or similar, the drawings and the appointment agreement for other consultants.

The CA usually also has a number of set activities to undertake, details of which are determined by the building contract itself, such as:

- **Provision of information**: The CA must ensure the provision of information, the supply of documents, drawings and setting out, as well as the provision of any additional information.
- **Financial matters**: The CA should be able to certify e.g. the amount of interim payments to be made

by the Employer to the Contractor, while specifying to what the amount relates and the basis on which that amount was calculated. The building contract requires certificates to be issued to the Employer with a copy to the Contractor. Furthermore, he should take the consideration to Interim valuations that must be made by the Quantity Surveyor whenever the CA considers them necessary. At last, the CA must send the computations of the Adjusted Contract Sum to the Contractor.

- **Supervision**: The CA should be able to complete the following tasks:
  - ✓ Approve the quality of materials or goods or of the standards of workmanship – where and to the extent that approval is a matter for the CA, such quality and standards shall be to his reasonable satisfaction.
  - ✓ Instruct the Contractor.
  - ✓ Obtain the Contractor's consent.
  - ✓ Issue to the Contractor on behalf of the Employer identifying the part or parts taken into possession and giving the date when the employer took possession.
  - ✓ Consent to the removal of unfixed materials on site 'in writing' or to sub-letting
  - ✓ Make a fair and reasonable extension of time for completion of the Works or Section in writing.
- **Miscellaneous**, such as:
  - ✓ Undertake the role of Construction Design and Management (CDM) Coordinator, unless someone else is identified in the articles (the CA may also carry out some of the functions of the Quantity Surveyor if named as such in the articles).
  - ✓ Give notice – identifying default by the Contractor prior to termination.
  - ✓ Direct the Contractor for the integration of the design of the Contractor's Designed Portion with the design of the Works as a whole.

It must be clarified that some of the above-mentioned activities are discretionary ('may'), while others are mandatory ('shall'). At the same time, the CA should accept and respond to various notifications, advice, information, requests, proposals and applications as part of the daily administration duties. It is also important that all these things, but particularly notices and certificates, are issued by the correct party and sent to the correct party, following, in some cases, a quite specific procedure. If, for example, a Notice is required to be issued by the Employer it must not be issued by the CA, although the Employer will probably expect the CA to advise on the form and timing of that Notice.

It is recommended that the CA makes sure that the terms of appointment define clearly the duties and roles and where they are not clear, have them clarified. The CA will need to be clear where the responsibility for ensuring compliance with the specification of works rests, not just for specialist items (e.g. M&E services or structure) but also construction. Where a designer is employed for works within the competence of the CA the boundaries may be blurred and difficult to maintain.

Before the start of the works it will be necessary for the CA to ensure that the employer has appointed appropriate professionals to monitor the works for compliance with the building contract. Those appointments will need to allow for:

- ✓ sufficient inspections of the works to verify that they comply with the building contract
- ✓ the provision of information and documentation to the CA in a timely manner to ensure that the CA can issue instructions to the contractor within the time limits imposed by the building contract, or any documentation that has been issued, e.g. an information release schedule
- ✓ the witnessing or undertaking of any testing or commissioning that is necessary to verify that practical completion has been achieved.

If defective workmanship or materials are found or suspected, the CA should be aware of the building contract provisions available that may allow the CA to:

- ✓ request information to prove that materials are in accordance with the specification
- ✓ issue instructions for opening up
- ✓ issue instructions to remove work, materials or operatives from the site.
- ✓ The CA can then follow through with the arrangements provided for in the building contract.

There may be occasions where the works, when opened up, are found to comply with the building contract; in such cases there may be an opportunity for the contractor to claim for costs. It is the CA's responsibility to advise the employer of this possibility and discuss it before the instruction is made.

Other considerations

<u>*General health and safety*</u>: It is important for the CA to be aware of health and safety in its widest sense, i.e. the issues of the CA's own personal health and safety whilst visiting the site, the general health and safety measures on site and the health and safety of those affected by the works.

While visiting the site, the CA will also need to follow the contractor's own health and safety procedures. More specifically, it may be required by the contractor that the CA attend the contractor's site induction, which will outline the site health and safety rules and advice of any particular risks and hazards on the site and how to deal with them. The proper health and safety personal protective clothing and equipment should be worn on site at all times or as directed by the contractor's site manager. As a professional within the construction industry it is good practice for the CA to set a good example of commitment to best health and safety practices at all times.

<u>*Environmental legislation*</u>: The requirements and obligations to meet environmental legislation are constantly growing and changing, and it is recommended that the CA keeps a close eye at such changes. Environmental legislation not only impacts on the design of buildings but also on the process of construction. There are growing demands on sourcing of materials, how they are transported, recycling on and off site and where waste products are disposed of.

It is important that the CA is aware of the legislative obligations and of how the latter affect the contract works. This might include:

- ✓ ensuring that proper investigations have been carried out before the works commence on site (e.g. for asbestos containing materials)
- ✓ evidence of sourcing of materials
- ✓ appropriate disposal of waste materials
- ✓ any particular protection measures for flora and fauna
- ✓ noise generated by the works.

<u>*Statutory obligations*</u>: The CA must be aware of the general current legislation that may affect the conduct of the building contract and the contract works, as well as of the statutory obligations that are specific to the works or site of the works. Consents, approvals or awards are possible to contain numerous obligations which, at a simple level, might require approval of materials for the external finishes, and more onerously they might require liaison with local residents or completion of certain

elements before occupation or use may be permitted. These obligations can have an impact on the programme and the sequence of work and thus, particularly where the obligations fall on the employer, it is the CA who has to make sure these obligations are undertaken so that the works can proceed uninterrupted.

More severe obligations exist while working on listed buildings or, in some cases, in conservation areas. The extent of work will be limited by the wording of the consents and it is important for the CA to obtain copies of all relevant documents before the building works commence, and to make sure that all concerned are familiar with the obligations contained in them.

Insurance: Whilst the CA should have a broad understanding of the insurance provisions within the selected building contract, the CA has a duty to recommend to the employer that they get their own specialist advice on insurance cover, in terms of level, scope and relevance to the works and provisions of the building contract. The CA should check that all the appropriate insurances (e.g. public liability) are in place at the time the building contract is signed; in practice, for even what appears to be relatively simple works, the contractual insurance provisions can prove to be quite time consuming to arrange ready for the commencement of the works.

1.1.4 Checklists

A set of typical – yet not exhaustive - checklists are presented herein, as a guide, but it should be clarified that not all the suggested items are appropriate for all projects:

Pre-commencement phase

a) Obtain copies of the following from the employer and be satisfied that all is in order:
- ✓ written employer authority accepting tender/ quotation
- ✓ written employer authority to commence works
- ✓ planning permission/listed building applications and approvals
- ✓ reserved planning matters identified and process for obtaining approval established
- ✓ building regulations approval
- ✓ hoarding licence
- ✓ road closure notice
- ✓ wayleaves/rights of way
- ✓ oversailing licence
- ✓ party wall agreements
- ✓ archaeological notice
- ✓ asbestos notice
- ✓ fuel/chemical/refrigerant tanks/pipes notices:
- ✓ live services:
  - – underground
  - – above ground
  - – overhead.

b) Obtain copies of the following from contractors and be satisfied that all is in order:
- ✓ tax certificate
- ✓ VAT certificate

- ✓ bank details
- ✓ insurance certificates:
  – employer's insurance broker to approve
  – renewal dates
- ✓ performance bond
- ✓ parent company guarantee
- ✓ warranty
- ✓ master programme
- ✓ information required by dates
- ✓ Names and contact details of key project personnel
- ✓ road closure notice.

c) Agree the following and confirm in writing:
- ✓ persons authorised to issue instructions
- ✓ system for issuing and confirming instructions
- ✓ employer's approval procedure for instructions/ changes
- ✓ names of key personnel, responsibilities and contact details
- ✓ procedure for drawing approvals, distribution and issue
- ✓ boundaries of the site and site restrictions (cross reference to tender documents)
- ✓ works to be sublet by contractor and approval procedure under provisions of the contract
- ✓ insurance claims notification and procedures.

<u>Construction phase</u>

a) General
- ✓ All contract documentation to be kept in fireproof lockable storage, if possible
- ✓ All instructions, confirmations, approvals, records to be issued in writing
- ✓ All information, documents and correspondence to be 'date received' stamped
- ✓ Confirm date that contract works commenced on site
- ✓ Confirm contract completion/sectional completion dates

b) Financial matters
- ✓ Certificates issued in time as stipulated in the building contract
- ✓ Procedures during holiday and sickness periods
- ✓ Valuation dates
- ✓ Employer payment procedures, e.g. invoice / accounts payable dept.
- ✓ Employer latest payment dates
- ✓ Employer payment method, e.g. BACS / cheque collected / cheque posted
- ✓ Indemnity for payment of materials off site – compliance with contract requirements

c) Records (agreed by all parties)
- ✓ Weekly site staff, labour and plant
- ✓ Daily weather and effect on the progress of works
- ✓ As-built programme
- ✓ Progress photographs
- ✓ Concrete / mortar cube results

- ✓ Test certificates
- ✓ Sub-contractors employed and works carried out
- ✓ Major materials suppliers

d) Instructions, confirmations and approvals
- ✓ Dated, reference, revision and author
- ✓ Instructions for expenditure or omission of all provisional sums
- ✓ Instructions, changes, variations and drawings issued under cover of CI/CVI
- ✓ Reasons for instruction, change or variation
- ✓ Revised drawings to stipulate amendment
- ✓ Postponed/deferred/suspended works to be instructed under AI/CAI
- ✓ Extensions of time/revision to date for completion
- ✓ Consent to sub-letting

e) Insurances
- ✓ New insurance certificate at renewal date

<u>Post-construction phase</u>

a) Notifications required at practical completion
- ✓ Employer's insurers (insurance then becomes the employer's responsibility)
- ✓ Utilities (employer then becomes responsible for bills), for example:
  - – water and sewage
  - – gas
  - – electricity
  - – telephone
  - – electronic data.
- ✓ Local authority (rates and taxes then become the employer's responsibility)
- ✓ Funders – P.C. issued to Contractor
- ✓ Set date for inspection before end of rectification period

b) Contractor leaving site
- ✓ Contractor's personnel and contact details
- ✓ Procedure for dealing with defects
- ✓ Re-direct contractor's post

c) Archiving original signed contract information – fireproof, safe and easily accessible
- ✓ Contract
- ✓ Design agreements
- ✓ Other specialist appointments
- ✓ Warranties
- ✓ Guarantees
- ✓ Final account
- ✓ Certificates, for example:
  - – completion of making good defects
  - – practical completion
  - – sectional completion

– partial possession
– revision to date for completion.

d) Archiving other contract information (originals where possible) – fireproof, safe and accessible

- ✓ Employer’s requirements
- ✓ Contractor’s proposals
- ✓ Bills of quantities
- ✓ Specifications
- ✓ Contract instructions
- ✓ Construction drawings
- ✓ As-built drawings and records
- ✓ As-built programme
- ✓ Site progress photographs
- ✓ Ground remediation records and certificates
- ✓ Concrete cube test results
- ✓ Other test results
- ✓ Technical queries and matters
- ✓ Site meeting minutes
- ✓ Contractor’s insurance details
- ✓ CDM documentation.

1.2 Keeping up the contractual terms of performance

1.2.1 Assessing whether the selected components and tools used fit the project requirements

A very important parameter that has to be taken into account during the procedure of examining the issue of keeping up of the contractual terms of performance for a water energy efficient project, is the fact that all the selected components as well as the tools that have been used for the preparation of the hydraulic installation must fit the requirements that are mentioned during the approved project planning.

The designer of a water–energy efficient plumbing system (especially in the case of non-residential buildings) should pay close attention to the local codes, the Uniform Plumbing Code (UPC), and the International Plumbing Code (IPC) when sizing water supply piping systems. He actually coordinates the appropriate type of fixtures in the different areas of the building, so close coordination is required for code requirements, number and placement of the plumbing fixtures. As a consequence, since the needs of each elaborated project present from slight to larger differentiations, it is very important for the supervisor to be able to assess whether the tools and components used each time, actually meet the predefined requirements of the respective project.

The designer has also to be familiar with the manufacturer's installation instructions concerning all the specified equipment and components. Thus, he shall incorporate the installation instructions as these are “recommended” by the manufacturer, into the bid documents in addition to the manufacturer’s “required” installation instructions.

The supervisor of a water-energy system is responsible of supervising and inspecting the entire plumbing and drainage work and shall take care of faithfully enforcing all corresponding laws, ordinances, and rules. Throughout the supervision of the project, at the time of inspection, the supervisor shall verify that all installations fully comply with the predefined (in the project) requirements. For this reason, the manufacturer's installation instructions shall be available on the job site at the time of inspection and of start-up.

1.2.2 Assessing whether the selected components are correctly positioned in the circuit

The main purposes of a plumbing system are to assure an adequate and potable supply of hot and cold water to the residents of the building, as well as to drain all wastewater and sewage discharge from the fixtures into the public sewer or to a private disposal system. Having the role of supervising the hydraulic system, the supervisor must be able to identify any possible inadequacies in the structure or any other code violations.

The *piping* of a house service line must be as short as possible. The elbows and the bends should be kept to a minimum level since they reduce water pressure and, therefore, the supply of water to fixtures in the house. Furthermore, the house service line must be protected from freezing. One and a half meters of soil is a commonly accepted depth to bury the line to prevent freezing (although this value varies, from country to country). The materials that are used must be approved plastic, copper, cast iron, steel or wrought iron and also compatible with the type of the used pipes.

The hot and cold water main lines that are usually hung must be neatly installed and supported by pipe hangers or straps of sufficient strength and number to prevent any possible sagging. The hot and cold water lines should be approximately 15 cm apart, unless the hot water line is insulated. This is to ensure that the cold water line does not pick up heat from the hot water line.

The supply mains have to possess a drain valve stop and a waste valve to remove water from the system for repairs and these have to be on the low end of the line or on the end of each fixture riser. The fixture risers start at the basement main and rise vertically to the fixtures on the upper floors. In one-family dwellings, riser branches will usually proceed from the main riser to each fixture grouping. In any event, the fixture risers should not depend on the branch risers for support, but should be supported with a pipe bracket.

The size of basement mains and risers depends on the number of fixtures supplied, while in houses that do not have any basement, the water lines are preferably located in the crawl space or under the slab. The water lines are sometimes placed in the attic; however, because of freezing, condensation, or leaks, this placement can result in major water damage to the home. In two-story or multistore homes, the water line placement for the second floor is typically between the studs and, then, for the shortest distance to the fixture, between the joists of the upper floors.

Also, the issue of the hot water safety is of very crucial importance. Water heater thermostats should be set at about 49°C for safety reasons (also, in order to save 18% of the energy used at 60°C). In addition, the installation of antiscald devices for faucets and showerheads is necessary for the of the water temperature in order for buns to be prevented. These devices must be installed and calibrated by a water technician. Most hot water tank installations now require an expansion tank to reduce pressure fluctuations and a heat trap to keep hot water from escaping up from pipes.

The valves that are used in a water system must allow the system to be controlled in a safe and efficient manner. The number, type, and size of valves required are always interconnected with the size and the complexity of the plumbing system.

The water heaters (involving a space for heating the water and of a storage tank) consist of another very important part of the circuit, so very attentive care has to be taken, especially as far as the fitting of a temperature-pressure (T&P) relief valve is concerned. The installation port for this kind of valves can be either found on the top or on the side of the tank near the top, while they should not be placed close to walls or door jambs, where they would be inaccessible for inspection and use. The importance of a (T&P) valve is high since it shall operate when either the temperature or the pressure becomes too high due to an interruption of the water supply or a faulty thermostat.

1.3 Regulations and standards

Construction management is challenging, in no small part because the industry is governed by a plethora of regulations. So what should contractors do to ensure noncompliance issues don't lead to delays or work stoppage? Regulatory compliance may seem daunting, especially for those new to the construction industry. Step one on the road to managing construction compliance is straightforward, even if it might be time consuming: *Learn the regulations that apply to your business*.

Beyond the contractual agreements between the owner, contractor and subcontractors, some common regulations in the construction industry include:

- Building codes.
- Insurance and bonding requirements.
- Credit and background checks.
- Wage and union payroll agreements.
- Lien requirements.
- Safety regulations.

These are a lot of hoops to jump through to ensure a successful end product. Any one of these issues falling through the cracks can bring work screeching to a halt while it is addressed. It can also present significant risk to the contractor via penalties, lawsuits or other conflicts.

Some requirements, like safety regulations, are fairly easy to learn, since relevant standards for the construction industry exist and apply to contractors in the various countries. Building codes, insurance requirements and bonding requirements can vary by location, though. The contract administrator should make sure he/she checks in with the relevant authorities in his/her city and state so that he/she knows what applies to each specific project.

Literature review confirms that projects experience cost and schedule overruns due to unidentified regulatory compliance issues and the impact is negative in most cases. However, these studies also suggest that identifying and addressing regulatory compliance would lead to successful completion of projects and useful project outcomes. Experience shows that regulatory compliance should be integrated into a project at its conception and needs to be followed up until the project is completed. Finally, project culture should be that regulatory compliance is a responsibility of all the parties involved in the project, and not a game of hide and seek with those deemed to "own" compliance risk.

As Project Management regulatory compliance basics the following could be listed:

- Include the regulatory impact assessment process at project initiation
- Add compliance to schedule of tasks
- Assign regulatory management responsibility
- Map and understand regulatory requirements
- Know the regulators and their expectations
- Establish and maintain a dialog with regulators
- Monitor for any changes in regulation
- Be aware of regulatory overlap and conflict
- Confront compliance difficulties with candor
- Respect the internal compliance approval and regulatory appeal processes

On the other hand, since the existence of a standard does not always ensure that the selected and/or used products indeed meet this specific standard, a series of checks have to take place and these are accomplished thought the assessment of the required conformity. The assessment of the conformity of a product, material or device is equal to a procedure of testing and verification leading to the fact that this certain product, material or device indeed meets the specification that has been developed.

There are at least three types of certification: where the manufacturer or seller self-certifies and guarantees the product by warranty or contract; where the manufacturer or seller obtains verification by a contract laboratory; or where the specific commercial product (not just the class of product) has been evaluated by a credible independent third-party testing or certifying organization that is in no way related to or a part of the manufacturer or seller, and which has a system for policing the validity of its certifications.

The quality of the component parts of a plumbing system together with the assembly skills of the person who shall install the system constitute very important parameters in view of the durability and the quality of the plumbing system itself. Thus, the products and the materials used must meet a certain level of quality for the entire system to function safely or hygienically.

The majority of industrialized countries have established a series of national standards or codes that set out the minimum requirements for the material specifications, design and use of specific plumbing products. However, some countries have adopted an approach according to which the existing level of detail should be minimized, whereas others are very prescriptive.

The countries that are members of the International Organization for Standardization (ISO) may have chosen to adopt the ISO framework as a minimum standard set for plumbing products and materials, while the WHO Guidelines for Drinking-water Quality should be used as reference in decisions concerning health-related matters. It is important that on country level the commonly used plumbing products and materials are of the same type, so as to take advantage of economies of scale in manufacturing and to ensure easy accessibility.

The selection of the suitable products used in a plumbing system is of outmost importance. The following issues should be investigated concerning the suitability of a product:

- ✓ Is the product or material under consideration suitable for the application or purpose?
- ✓ Will it be harmful to the health of the community in its normal use?
- ✓ Is there a risk of these materials being released into the environment (e.g. the water) in the first instance or after the working life of the product or material has expired?

WHO as well as many national authorities have developed guidelines or standards that set out the maximum acceptable levels of metals, chemicals and / or other contaminants in public drinking-water supplies (WHO 2004a). These guidelines are then converted to apply to contaminants that may leach from the fixtures and the associated network of a piping system.

The total of the pipes, valves, taps and other fittings that are used for the supply of drinking-water or for the removal of wastewater must not contain harmful substances (e.g. lead, cadmium, arsenic) above the specified amount that could leach into the water. In addition, these fittings must be capable of conveying water at a nominated pressure within a prescribed environment, and also be of a sufficient strength to contain anticipated internal pressures.

At last they shall be capable of bearing external pressures in case they are intended to be buried. The impact of environmental factors such as heat, cold, expansion, contraction, corrosion, pH and bacteria levels also need to be taken into examination.

Unit 2: Necessary tests & procedures to secure inspection and commissioning

Introduction / General description

In the 2nd Unit of Module 2 of the WEE Course, the focus is set on the supervision during the phase of the (inspection and) commissioning of a water-energy project. Thus, the list of necessary tests and other procedures that are necessary in order to secure inspection and commissioning are presented to the participants in the training, in order to improve their knowledge of:

- the tests and procedures to secure inspection and commissioning of the water-energy efficient system,
- the regulations and standards (local, national, international) applicable in the inspection and commissioning of the water energy-efficient system

More specifically, the commissioning procedure is analytically addressed. The tests and procedures for the testing and commissioning are further and detailed described, focusing on the separate and consecutive steps and phases that have to be followed. Finally, the relevant regulations, guidelines and standards applying to the commissioning of systems are briefly, yet fully, presented.

Scope – Expected results

After attending this Learning Unit 2 of Module 2, the trainees will be able to:

- perform the necessary tasks for the testing of the water-energy system in consideration,
- identify and describe the appropriate tools to secure proper inspection and commissioning of the water-energy system,
- efficiently check-out the water-energy system,
- provide an estimation of the work to be carried out for the system testing, inspection and commissioning.

Key words / basic terminology

Planning, tests, procedure, inspection, commissioning, pre-commissioning, site acceptance testing, standards, guidelines, regulations.

2.1 Planning for commissioning

The plumbing systems are nowadays getting to the integrated building system action, while they are taking on complexities previously unknown. Most of the new plumbing system designs are a result of the desire for sustainable buildings, particularly with respect to water conservation / efficiency, waste water reduction, and energy / carbon footprint savings.

In the United States, for example, the Green Building Council's Leadership in Energy and Environmental Design (LEED) program requires that a building's domestic hot water system(s) is commissioned as a prerequisite for certification. The LEED rating system has also been directly responsible for many of the innovative plumbing systems currently being designed and installed in buildings. These include, although not limited to:

- ✓ Rainwater collection and use for flushing toilets, irrigation, and other non-potable applications;
- ✓ Grey water collection for flushing toilets, irrigation, and other non-potable applications;
- ✓ Solar water domestic water heating;
- ✓ Waste energy recovery for domestic water preheat; e.g., transferring heat from chiller condensers, boiler blow-down, boiler exhaust stacks, etc.;
- ✓ Irrigation system flow and pressure monitors;
- ✓ Sub-metering water consumption;
- ✓ Time-of-day scheduling of domestic water distribution; and
- ✓ Composting toilets.

Each of the above systems, partially because of their unique nature and partially because of their inherent controls complexity, consist of excellent candidates for the commissioning process.

The commissioning begins with the development of a project-specific Commissioning Plan. The Commissioning Plan consists of the roadmap for the commissioning process through pre-design, design and construction of the system. It lays out both the roles and the responsibilities for each team member during the various phases of the project, identifies the systems to be commissioned, and defines the level of rigor for each subsystem. What is of crucial importance is that the elaboration of a commissioning plan offers the opportunity for a timely and early establishment of expectations, so that later on no unpredictable surprises arise concerning the project.

The commissioning process is facilitated by a Commissioning Professional (contractor). However, commissioning is a teamwork procedure / strategy and a primary role of the Commissioning Professional is that of a coach. The team is comprehensive and includes the owner's project and operations staff, the design team and construction team.

The following are some of the fundamental elements of commissioning in project chronological order:

- ✓ Prepare Commissioning Plan;
- ✓ Define owner's systems performance acceptance criteria;
- ✓ Review design documents for compliance with acceptance criteria;
- ✓ Prepare commissioning specification section for bidding documents;

- ✓ Review shop drawings and equipment submittals for compliance with acceptance criteria;
- ✓ Observe installation for future maintenance and operations accessibility issues;
- ✓ Verify that equipment is installed and started per manufacturer's recommendations;
- ✓ Provide appropriate time in the construction schedule for coordinating and executing "system" level activities such as air and water testing and balancing, controls programming and checkout, and inter-system communications;
- ✓ Verify functional performance of the systems and integrated systems to confirm final compliance with the acceptance criteria;
- ✓ Train owner's staff in equipment maintenance and systems operation;
- ✓ Provide system-level operations documentation for future reference and training of owner's staff;
- ✓ Develop Re-commissioning and/or on-going Commissioning plans for the owner's execution throughout the life of the facility.

Launching the commissioning procedure, the Contractor must prepare a very detailed Commissioning Plan to cover all aspects of the project delivery phase, including civil, mechanical and electrical construction, factory acceptance testing (FAT), pre-commissioning, dry-commissioning, wet-commissioning, process commissioning, site acceptance testing (SAT), proving and training. The Commissioning Plan is to be considered as a live document, to be updated to accommodate changes during the delivery of the project and inclusion of new information as applicable.

A draft plan is to be produced prior to completion of detailed design (or upon award if construct only), providing high level details of the commissioning process, a register of inspection and test plans (ITPs) and check-sheets and preliminary program details for review by the CA Team Representative.

As a minimum the Commissioning Plan must include the following:

1. Overview of commissioning methodology and stages.
2. Details of risk assessments that have been undertaken to facilitate the development of the plan and methodologies stated.
3. Details of the construction stage procedures inclusive of test plan for the construction stage covering all items of process, civil, mechanical, software and electrical construction.
4. Details of the pre-commissioning stage procedures inclusive of test plan covering all items of plant and equipment.
5. Details of the dry commissioning stage procedures inclusive of a software download plan, commissioning procedures and test methodologies for all key testing and commissioning activities.
6. Details of the wet commissioning stage procedures inclusive of commissioning procedures and test methodologies for all key testing and commissioning activities.
7. Details of the SAT/integrated commissioning stage procedures inclusive of cutover, test methodologies for all key testing, commissioning and O&M training activities.
8. Details of the operational test / reliability period stage monitoring and testing methodologies activities.
9. Details of the process proving stage monitoring and testing methodology.

10. Software Download Plan, software FAT (SFAT), software SAT (SSAT) and required operational change requests for the available Integrated Instrumentation, Control, Automation & Telemetry System (IICATS).
11. Detailed ITPs and inspection and test check sheets (ITCs), incorporating identification, recording and verification of:
    a) all relevant asset information required for entry into the Water Corporation technical asset register (TAR)
    b) all civil, structural, mechanical, electrical, process and control (software) checks necessary for
    c) testing, commissioning and operation of the facility
    d) all key testing and commissioning activities as identified in the prepared procedures and methodologies
    e) all performance targets and project objectives as per the requirements of the Contract
    f) all equipment supplier recommended checks and tests
    g) the corresponding acceptance criteria that the Contractor must use for establishing the conformance of the Works with the requirements of the Contract
    h) all hold, witness or surveillance points as per the requirements of the Contract, nominated by the CA Team or otherwise nominated by the Contractor.
12. A testing and commissioning program or schedule, defining:
    a) the work breakdown structure (WBS) adopted in order to detail Lot Management of the Asset(s)
    b) holdpoint dates
    c) all dates and periods for each stage of the commissioning process
    d) all required periods for notifications and submissions to the Water Corporation.
13. A "roles and responsibilities" matrix, identifying all personnel, stakeholders and sub-contractors who will be involved with all key testing and commissioning activities
14. Decision-making process to determine whether a system is operating satisfactorily
15. Procedure for recording, managing and rectifying any non-conformances.

The Commissioning Provider (CxP) works closely with the project team to integrate commissioning activities into the overall planning, design and construction schedule, to keep commissioning activities off the critical path, and to carry out site inspections with a focus on systems performance, operations and maintenance. A commissioning schedule is developed as section of a commissioning plan and it is updated throughout the project. The objective of scheduling commissioning activities is to integrate and coordinate them with other planning, design and construction phase activities.

Detailed integration of commissioning activities and tasks with the overall project schedule is critical to maintaining project milestones. The chart presented in Figure 1.1 illustrates how commissioning activities and tasks relate to typically occurring project activities.

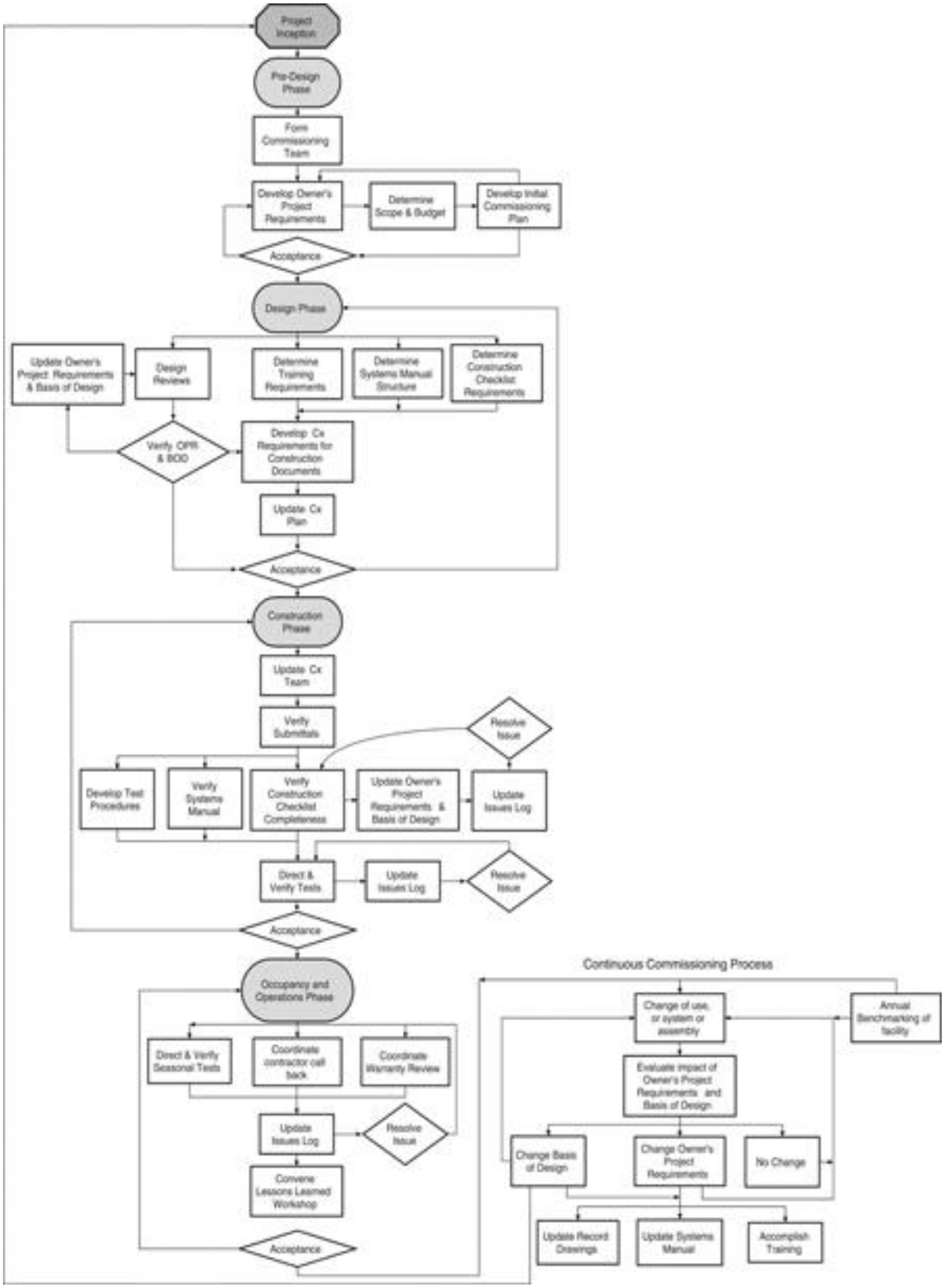

Figure 1.1: Commissioning Process Flowchart

[Source: ASHRAE GL-0 2013]

2.2 Tests and procedures for testing and commissioning of water-energy systems

2.2.1 Pre-commissioning

The first step that has to be implemented when referring to the inspection of a water-energy system is the "pre-commissioning", being the checking/verification of individual components of sub-systems for correct installation, configuration and operation. The Pre-Commissioning is performed on all new plant components once their basic construction or installation is complete.

The completion of pre-commissioning is required prior to the commencement of the commissioning procedure and it may include the following activities:

- ✓ Electrical energisation of motor control centres (MCCs) and field instrumentation
- ✓ Air compressor configuration - Setting of Load/Unload set points
- ✓ Valves checked for "clean" travel and correct sealing when closed
- ✓ Initial configuration and calibration of Field Instrumentation
- ✓ Motor Rotation Checks in Field mode
- ✓ Delivery of mechanical, electrical ITPs, FDS and SFAT documentation to IFC status
- ✓ Delivery of vendor manuals
- ✓ Instrument configuration in accordance with the IO list, units, ranges etc
- ✓ Valve, actuator and limit switch configuration
- ✓ Leak and pressure test water retaining structures
- ✓ Setting of pressure control/pressure sustaining and pulsation dampers
- ✓ Pump configuration
- ✓ Motor starter configuration and tuning.

Prerequisites for pre-commissioning

The Contractor must ensure the following are prepared and submitted to the Water Utility before the pre-commissioning procedure is launched. The requirements may vary depending on asset type and complexity of the project. Some of these items may form part of the Commissioning Plan submitted at the first stage of the commissioning:

- ✓ a completed Pre-commissioning Checklist;
- ✓ FAT and Inspection Report(s);
- ✓ where applicable, approved SFAT;
- ✓ ITPs and procedures for the pre-commissioning stage covering all items of plant and equipment;
- ✓ Installation Completion Reports accepted and endorsed by the Water Corporation's subject matter experts (SMEs);
- ✓ calibration certificates for equipment or instruments used for testing;
- ✓ all regulatory certificates and approvals required for the installation and the equipment obtained by the Contractor on Water Corporation's behalf;
- ✓ where applicable, MDRs for pre-fabricated equipment;
- ✓ all drawings including P&IDs marked-up to a Work As Constructed (WAC) condition;
- ✓ NOE (as applicable);
- ✓ where applicable, issued for construction (IFC) copies of the FDS and PEFD data loaded into TAR;
- ✓ completion of any required preliminary training programs (vendor training, for example) where applicable, the asset Hazardous Area Dossier needs to be completed/updated as applicable to

EEHA (Electrical Equipment in Hazardous Areas) requirements and submitted for review before power can be applied to any electrical equipment or cables in a hazardous area;

- ✓ Construction completion documentation must be completed and submitted to the Water Corporation for approval;
- ✓ Commissioning and Cutover Plan Review meeting held;
- ✓ Updated Defects Register.

Pre-commissioning activities

1) Electro-mechanical and mechanical equipment

Electro-mechanical and mechanical equipment checks and testing shall include the following, where applicable:

- ✓ Verify that equipment has not been damaged by transport or installation
- ✓ Flushing of water retaining structures
- ✓ Service pressure test pipework and valves for leaks
- ✓ All delivery blocks and oils have been removed and equipment is ready for commissioning
- ✓ Runs of rotating equipment, rotating direction, and performance of electric motors
- ✓ Functional tests of equipment
- ✓ Testing and adjustment of safety devices
- ✓ Recording of key test / set points in TAR (specifically PRVs and pressure vessels)
- ✓ Check that equipment is correctly lubricated and lubrication reservoirs charged with suitable lubricant
- ✓ Correct functionality of all site connected items on each motor drive, including Local Control Station
- ✓ Latch/Emergency Stop (LCS) push button, thermistor, motor anti-condensation heaters, etc.
- ✓ Clearance, end play and operation of major bearings
- ✓ Alignment of drive systems (by dial, feeler gauges and stainless shims or equivalent laser alignment), tightness of couplings, mounting of bolts, vibration, etc.
- ✓ Correct installation of guards, trip wires and other personnel safety equipment
- ✓ Measure and record kW and current draw of each motor at no load
- ✓ Measure and record the power factor at various loads, where possible
- ✓ Level control of pumps
- ✓ Valve positions and operation
- ✓ Ensure the system has been cleaned and flushed
- ✓ Ensure equipment storage plugs, locks etc. are removed
- ✓ Check of lifting facilities
- ✓ Registration of key equipment, (pressure vessels, bulk chemical storage tanks etc.).

2) Electrical equipment

Electrical equipment checks and testing will include the following, where applicable:

- ✓ Voltage tests
- ✓ Trip tests
- ✓ Functional tests
- ✓ Electrical integrity tests, including electrical tests for insulation, earth leakage
- ✓ Resistance to high voltage
- ✓ Testing and adjustment of safety devices

- ✓ Check of ranges/settings of equipment
- ✓ Instrument power up, configuration, including unit and range setting.

NOTE: Instrument setup and parameterisations details to be extracted from instruments and provided as part of O&M Manuals.

- ✓ Electrical continuity and electrical earthing tests
- ✓ Check maintained emergency and exit lights
- ✓ Check two way switching operation
- ✓ Check operation of photo-electric cell and override switch
- ✓ Check type, number and locations of light switches and GPOs
- ✓ Correct operation of all field connected items
- ✓ Electrical point to point checks
- ✓ Installation diagrams for installed instruments
- ✓ Visual inspection of labelling and terminations of electrical wiring
- ✓ Visual inspection of cable pits
- ✓ Visual inspection of electrical wiring on cable trays
- ✓ Visual inspection of electrical wiring in conduits
- ✓ Set up and programming of VSDs and soft starters
- ✓ Profibus network testing
- ✓ Fibre Optic testing (OTDR)
- ✓ Network redundancy testing
- ✓ Power redundancy testing.

NOTE: The setup is limited to motor nameplate details, motor protection settings and other parameters to enable "bump" testing of the motors.

Records of parameters are to be recorded and supplied prior to testing of any motors.

<u>3) HV Electrical works</u>

Electrical equipment checks and testing shall include the following, where applicable:

- ✓ Insulation resistance tests
- ✓ Voltage withstand tests
- ✓ Ductor tests
- ✓ Phase rotation tests
- ✓ Polarity checks
- ✓ Primary injection testing of CTs
- ✓ Secondary injection testing of protection relays.

Pre-commissioning completion requirements

When pre-commissioning is completed the Contractor must ensure the following requirements are fulfilled before commissioning commences:

- ✓ Asset Isolation Plans - if required
- ✓ Copies of WAC drawings available including P&IDs (redline mark-ups are permissible) and stored on site. A current copy of electrical drawings must be kept in the switch room or kiosk at all times once switchboards are live

- ✓ Manufacturer's trial run records/ test certificates of equipment available including performance tests
- ✓ Decommissioned and disposed assets list
- ✓ Supplier/vendor Instrument calibration records
- ✓ Updated Commissioning Plan
- ✓ Project Safety Plan covering the commissioning work including the required SWMS for the
- ✓ commissioning tasks
- ✓ Environmental Management Plan (EMP) covering the commissioning work of the project
- ✓ where applicable, draft Plant Operations Manuals for the asset (treatment facilities)
- ✓ where applicable, draft Process Equipment Asset Specifications for the asset (treatment facilities)
- ✓ where applicable, draft Plant Operations Manual, Plant Process Specification and Plant Asset Specifications (treatment facilities)
- ✓ where applicable, up to date FDS and PEFD
- ✓ where applicable, a completed SFAT has been conducted for the Asset(s)
- ✓ commissioning team and other critical personnel have sufficient training to enable asset to be commissioned
- ✓ if the Works change the hydraulics of the asset and network or impact flow monitoring equipment,
- ✓ then notify Hydrographic Services to recalibrate flow instrumentation
- ✓ where applicable, Software SAT (SSAT) scripts are available
- ✓ updated Project Risk Register
- ✓ proof of compliance with statutory and regulatory requirements
- ✓ defects/punch-list walk with key stakeholders completed
- ✓ updated defects register
- ✓ no category 'A' defects
- ✓ a completed Pre-commissioning ITP.

The Contractor must pre-commission all components, together with their ancillaries, and rectify any non-conformances in accordance with the Contractor's Quality Plan. On water assets, the asset must be appropriately washed / cleaned / disinfected and followed up with appropriate sampling to demonstrate cleanliness before proceeding to wet commissioning.

2.2.2 Commissioning

Commissioning will be performed on components and sub-systems, once pre-commissioning is complete. The Commissioning Team will also undertake testing activities in conjunction with suppliers or vendors where applicable.

Commissioning will be conducted in 3 stages, as follows:

a) *Dry Commissioning* includes dry tests on equipment and systems SAT, fail safes and operation

b) *Wet-Commissioning* is the process used to determine the control system operates in accordance with the FDS and involves the initial setting of control loops. This process should determine that all process controls and safety interlocks are fully operational.

c) *Process Commissioning* (Only required on assets with a process component) relates to the demonstration that the upgraded asset and all associated components integrate and operate as intended. The plant must be brought on-line with product and all the systems necessary to operate the asset must be fully tested and commissioned.

Dry-commissioning

This phase will typically consist of testing dry running equipment, in particular electrical power, component testing and "end to end" testing of the RTU/PLC, SCADA/IICATS interface and mechanical equipment as applicable. These activities will be captured on dry-commissioning ITPs and ITCs and will be signed off prior to Wet-Commissioning by the relevant Commissioning Representative.

Dry-commissioning will include, but it is not limited to:
a) initial configuration of Operator set points and alarm values;
b) initial configuration of PRVs, PCVs and associated hardware;
c) confirmation of 'Fail Safe' mechanisms;
d) network communications verification;
e) checking the electrical instrumentation and control systems input and output signals in conjunction with the RTU/PLC and SCADA/IICATS system;
f) SCADA/IICATS picture testing and screen navigation;
g) checking equipment operation and remote lockout from LCS;
h) rotation checks (bump test) of all pumps and motors;
i) dry-run functional tests, where possible;
j) calibrate and test all instruments and analysers;
k) simulate fault condition tests;
l) check interlocks, RTU/PLC and SCADA/IICATS logic;
m) alarm handling, including local and SOC Alarms;
n) dry tests for the asset including but not limited to all mechanical and electrical equipment;
o) instrumentation, control and SCADA systems, alarm annunciators, set points.

Wet-commissioning

Wet-commissioning will be performed on plant components and sub-systems, once dry-commissioning is completed. Where appropriate, wet-commissioning will be carried out using potable / recycled water. Wet-commissioning is the process used to determine the control system operates in accordance with the FDS and involves the initial setting of control loops. This process should determine that all process controls and safety interlocks are fully operational.

Facilities may be broken down into sub-systems composed of interrelated equipment and other components for which functional testing has been completed. Each system will then be tested to demonstrate that it operates in the manner designed. Individual commissioning ITP's will be developed for each sub-system that is to be tested and signed off.

Wet-commissioning will include, but it is not limited to:
a) any Statutory approvals have been obtained before wet testing (e.g. approval to discharge);
b) initial priming of pumps and process pipework;

c) initial setting and confirmation of process control loops;
d) initial calibration of process instruments;
e) vibration and noise testing of mechanical equipment identified in Technical Specification – Mechanical;
f) all instruments have been calibrated and test/calibration sheets have been completed - these must include any internal setting/set points and a hard copy output detailing the parameters set (particularly applicable to drives or instruments with internal ranges and parameters);
g) check performance of equipment to the requirements of the Contract;
h) check integration of controls systems particularly with off-site equipment;
i) wet-run performance tests with one of the scenarios on the most critical operating condition;
j) submission of power factor correction report as applicable;
k) submission of harmonic analysis and correction report as applicable.

Not all equipment or controls may be able to be tested before wastewater or process fluid is introduced. The Commissioning Plan must clearly state if this is so and must include steps to manage the associated risk. The Contractor must carry out all the necessary adjustments until the Components are ready and suitable for starting and running under all operating conditions.

Tests must be carried out to verify that the Components will meet operational requirements of the Contract under conditions replicating the operational range as much as possible. The scope must include any specific tests nominated in this Contract for particular items of plant and equipment. The Contractor is required to simulate the conditions necessary for the proper operation of all Components including stoppages due to simulated power failure.

Process commissioning

The Process commissioning phase relates to the demonstration that the upgraded asset and all associated components integrate and operate as intended. The plant must be brought on-line with process fluid/product and all the systems necessary to operate the asset must be fully tested and commissioned. The process commissioning may happen altogether or by sub-system, according to the natural flow of the asset's processes, and is aiming at:

a) final tuning of process control loops
b) final calibration of process instruments
c) confirmation of process flows
d) confirmation of effluent quality
e) update of all project documentation to WAC status
f) delivery of Commissioning ITPs.

Process commissioning must include the following:

a) **Integrated Asset Commissioning**, which is the phase in which all newly commissioned and existing systems are integrated together to be tested and operated in their final process arrangement.

b) **Process Optimisation**, which is the period of operation with process fluids immediately following cut-over or seeding in which equipment and control setting are adjusted and tests conducted for a period to ensure the Components operate as intended.

The Contractor must commission all components with process fluid to prove the components operate reliably in actual flow conditions with fully automatic operation including correct start up, shutdown and emergency shutdown sequences, and stoppages due to simulated power failure. Each component must be tested over its full range of operating conditions which can be reasonably simulated / achieved at the time of the tests. The tests must be designed to demonstrate the component's compliance with design hydraulic, mechanical, electrical control and occupational noise criteria.

2.2.3 Site acceptance testing (SAT)

Site Acceptance Testing (SAT) is formalised testing prior to final cutover and putting assets into ongoing operation. There are three key stages to SAT.

a) **Pre-SAT** is an internal SAT conducted by the Contractor to ensure all systems are performing as intended prior to the formal SAT

b) **SAT** is the formal test conducted prior to the introduction of process fluids and will be witnessed by the CA Team

c) **Operational Test** is the period of a number of continuous days, as specified (refer to Project Specification) during which the assets must operate reliably in the intended manner. For operational test, the asset must be selected in automatic sequence mode (all modes should be tested as applicable) and in automatic equipment control mode at the SCADA interface. Plant Operations Manuals must be adjusted as applicable based on actual asset operation.

Pre-site acceptance testing (PRE-SAT)

The Contractor is to conduct a Pre-SAT on all process or sub-systems prior to the formal SAT, to eliminate any wiring, software or equipment functionality issues. A Pre-SAT must be carried out once:
- ✓ the system or sub-system has been dry and wet commissioned
- ✓ the system or sub-system post FAT software has been downloaded.

The Water Utility will not normally witness the Pre-SAT but must have the right to do so. The signed copies of the Pre-SAT ITP must be available for review on the day of the SAT. The Pre-SATs must itemise and cover all tests associated with the relevant section of the FDS.

Site acceptance test (SAT)

SATs will include, but are not limited to:
- ✓ Functional Testing of all phases of operation
- ✓ PLC/SCADA system operation and Alarm Handling
- ✓ All alarms and control functions are operable (electrical simulation not acceptable)
- ✓ Functional check on interlocks and control systems for the entire plant
- ✓ Integration of the asset with existing operations
- ✓ Local, Remote testing of devices
- ✓ Duty/Standby/Assist testing of process units
- ✓ Functional testing of components and sub-systems
- ✓ Initial PID Loop tuning

- ✓ Flow, temperature and pressure control
- ✓ Other process performance testing and monitoring as required by the specification.

During FAT or SAT, if equipment is subjected to considerable wear and tear, it must be replaced by the same specification of new equipment at the Contractor's expense.

<u>Operational test</u>

Operational Tests must be carried out by the Contractor to prove compliance with the hydraulic, mechanical, electrical control and occupational noise requirements set out in the Project Specification and other parts of this Contract. During the Operational Test, Components or part thereof must be tested under the worst operating hydraulic and/or all loading conditions for a sufficient period of time to validate the performance of the Component.

All documentation including SOPs, O&M manuals, WAC drawings and Asset Management Maintenance Systems Data must be adjusted as required to reflect any modifications and the actual operation following Operational Testing. The acceptance criteria for the Operational Test is that the Component must operate continuously for a specified period of days, 24 hours a day (unless agreed otherwise by the Water Corporation) meeting all hydraulic, mechanical, electrical control and occupational noise requirements as stated in the Contract and other parts of this Contract, under automatic mode of operation without any category 'A' defects.

2.2 Conclusive benefits on Commissioning

Although the commissioning procedure may have been successfully completed and implemented, the commissioning itself does not replace the quality control component of a project but rather enhances the quality process on the jobsite. The quality control focuses on the static elements of the project, e.g., equipment, piping, conduit, installation coordination, etc. Commissioning goes a necessary step further to focus on how all of the static elements dynamically work together as systems. It is only through the interaction of system elements that the owner's performance requirements can be met.

The Commissioning Professional is the eyes and ears of the future operations staff during the design and construction process, and the commissioning process brings the long-term view of the facility to the forefront of all decisions. When there are decisions to be made with respect to budget, schedule, and quality, the commissioning process helps bring as much weight to the quality issues as is given to the other two goals. Quality will not always "win," but the owner will be able to make informed decisions with an understanding of the long-range cost of each decision.

To close the loop on the process it is essential that facilities engineering staff responsible for operating the systems are adequately prepared through training, documentation, and involvement in the commissioning process. Although the traditional project closeout activities include training of the owner's staff, that training is typically limited to the preventive maintenance and troubleshooting of individual pieces of equipment. Commissioning takes this further by focusing on systems operation training.

Systems training provides explanations of the system performance criteria and how the designers' systems will achieve those criteria. The goal of this training is to convey how all of the individual pieces of equipment are uniquely configured to operate as a "system." There is heavy emphasis on schematic diagrams and automatic and manual control sequences. And, in the interest of sustained proper operation of the equipment and systems, commissioning heavily emphasizes the importance of complete, accurate, and easy-to-use systems documentation, designed with the future operations staff in mind.

Concluding, the Commissioning offers a substantial benefit to the design and construction project by providing a framework in which the entire project team can successfully achieve their operational, schedule, and budget goals. However, the greatest value from commissioning accrues to the facility owner through focused planning, documentation, and training for the on-going operation and maintenance of the new systems.

The project team benefits from improved communication and coordination, on-time successful completion and turnover of the building to the owner, and far fewer call-backs after project completion. The owner receives a building that works at the time of occupancy, while the designers and contractors have a satisfied customer and a more profitable project. The owner's facilities team takes over a building that they understand and in which they have confidence. They are also given the tools to successfully serve their customers – the building occupants.

2.4 Applicable regulations and standards

The main guidelines and standards (local, national, international) that are applicable in the inspection and commissioning of systems are briefly presented in the following paragraphs.

So, the American Society of Heating and Air-Conditioning Engineers (ASHAE), an organization that is responsible for the elaboration of guidelines and standards in the field of commissioning, has a long history in this field, as follows:

- 1982 – ASHRAE forms Committee
- 1989 – ASHRAE Guideline 1 first published
- 1996 – First revision of ASHRAE Guideline 1
- 2000 - ASHRAE joins with NIBS to develop a universal process for commissioning
- 2005 – ASHRAE / NIBS Guideline 0 published
- 2007 – ASHRAE Guideline 1 revised
- 2007 - Existing Building Guideline Committee formed

The Commissioning Process is fully described in the **ASHRAE Guideline 0-2019** (the most updated version of the ASHRAE Guideline). Commissioning Process (Cx) is a quality-focused process for enhancing the delivery of a project by achieving, validating, and documenting the performance of facility elements in meeting the objectives and criteria of the Owner. Cx extends through all phases of new or major renovation projects, from redesign to Owner occupancy and operation, with tasks during each phase to ensure verification of design, construction, and operator training.

Whereas **ASHRAE/IES Standard 202** defines the minimum acceptable Cx for a project, ASHRAE Guideline 0 outlines best practices and establishes the order of phases in which the components of the Cx are best implemented. It provides a template for Cx Plans for specific facility elements or assemblies, and establishes common content that serves as a uniform method for achieving different levels of commissioning and meeting varying Owner's requirements. The guideline also serves as the foundation for authoring technical commissioning guidelines more narrowly targeted and focused on specific applications.

Appendices are included to assist in further understanding of the Cx. Based on specific project experiences, they suggest ways to improve current practices and illustrate a variety of Cx applications, with examples for developing the Owner's Project Requirements, Basis of Design, design criteria, design concepts, verification and functional performance testing requirements, operator training, and more.

This 2019 edition of ASHRAE Guideline 0 updates terminology to reflect an evolving whole-building Commissioning Process (Cx) and harmonizes terminology and its usage with that of ASHRAE/IES Standard 202. The purpose of **ASHRAE Guideline 0-2019** is to describe a Commissioning Process (Cx) capable of verifying that the facility and its systems meet the Owner's Project Requirements (OPR).

As far as the scope of the Guideline is concerned, the procedures, methods, and documentation requirements in this guideline describe each phase of the project delivery and the associated Commissioning Processes from predesign through occupancy and operation, without regard to specific elements, assemblies, or systems. ASHRAE Guideline 0-2019 provides the following:

a. Overview of Commissioning Process Activities
b. Description of the Commissioning Processes for each project phase
c. Requirements for acceptance during each phase
d. Requirements for documentation during each phase
e. Requirements for training of operations and maintenance (O&M) personnel.

The new **ASHRAE/IES Standard 202** (**Standard 202-2013 -- Commissioning Process for Buildings and Systems (ANSI Approved; IES Co-sponsored**) describes how to plan, conduct, and document this vital part of a successful project. Informative appendices provide sample documentation, including checklists, systems manual, reports, training plan, and more. It actually describes the Commissioning Process, the roles of the principle agents and stakeholders, and a framework for developing design documents, specifications, procedures, documentation, and reports. It also describes the general requirements for a training program for continued successful system and assembly performance.

The 2018 edition of Standard 202 includes updates to terminology and definitions. Supplementary guidelines (Guidelines 0, 1.1, and 1.5) are available in the ASHRAE Bookstore, while they provide specific and detailed information on how to implement the commissioning process for each major building/facility, system or assembly, and for various stages of facility development and operation.

Other relevant to project / building commissioning Codes and Standards are the following:

- ✓ AIA (American Institute of Architects) B211™—2007 Standard Form of Architect's Services: Commissioning—This fixed scope of services requires the architect to develop a commissioning plan, a design intent document, and commissioning specifications, based on the owner's identification of systems to be commissioned.
- ✓ ASTM (American Society for Testing and Material) Standard E2813-2012 Standard Practice for Building Enclosure Commissioning.
- ✓ The Building Commissioning Guide by General Services Administration (GSA), 2005.
- ✓ International Code Council (ICC).
- ✓ 2015 International Energy Conservation Code® (IECC®).
- ✓ 2015 International Green Construction Code® (IgCC®).

Unit 3: Supervision and monitoring of operation (Operational Supervision)

Introduction / General description

In the 3rd Unit of Module 2 of the WEE Course, the supervision that has to be implemented throughout the final phase of the operation of the project (system) is addressed. The operational supervision is further analysed into the "Condition Monitoring" and the "Condition Based Maintenance" explaining the reasons why these two procedures/strategies are suggested as necessary parts of the entire supervision process.

Scope – Expected results

After attending this Learning Unit 3 of Module 2, the trainees will be able to:

- incorporate the "Condition Monitoring" and the "Condition Based Maintenance" procedures into the wider procedure of the operational supervision;
- understand and focus on the advantages presented by the above mentioned procedures for the entire lifecycle of the water-energy project.

Key words / basic terminology

Supervision, operational supervision, Condition Monitoring, Condition Based Maintenance

3.1 The basics of operational supervision

Operational supervision is the process of overseeing the daily activities of a building or facility and managing the efficiency of its resources. This process involves making sure that each team within a facility has the supplies and resources they need to produce the company's services or products. It also includes supervising employee affairs, such as attendance, performance and professional growth. Hiring someone to provide operational supervision is often an essential step in securing the success of a business.

The responsibility of operational supervision usually falls on an operations manager or supervisor. An operational supervisor uses their field-specific knowledge and experience to guide and manage a certain team of professionals. For example, a production operational supervisor would be responsible for overseeing all activities in a production factory, while a distribution operational supervisor would do the same in a shipping facility. An operational supervisor's primary duties include:

- ✓ Training new hires and monitoring all employee performance
- ✓ Planning and enforcing budgets and delivery schedules
- ✓ Keeping inventory records and purchasing items whenever necessary
- ✓ Making strategic plans to improve efficiency and promote growth
- ✓ Setting short and long-term goals for the department and for individual employees
- ✓ Managing employees who are underperforming, with the assistance of HR
- ✓ Overseeing all customer service communication and intervening if necessary
- ✓ Changing and updating processes or policies that can be improved
- ✓ Communicating with upper management and reporting the department's progress

Operational supervisors are important additions to any organization. Their primary goal is to help the company grow and succeed by making everyday activities more efficient. They are constantly working to improve practices, increase employee performance and eliminate delays. Hiring a skilled and hard-working operational supervisor or manager helps a company to consistently produce high-quality products, while also maintaining employee satisfaction.

Some tips and strategies for how to maximize the potential of operational supervision in the workplace are:

1. Prioritize the customer.
2. Address problems at their source.
3. Invest in new technology.
4. Simplify processes.
5. Communicate effectively.

<u>1. Prioritize the customer</u>

Operational supervision is primarily concerned with what goes on within the workplace and how it affects the employees. However, the end-goal of all operational processes is to provide a product or service to a customer. The operational supervisor should constantly be setting and working towards goals that have the customer's best interests in mind. The overall purpose of increasing efficiency, streamlining a process or improving employee performance should be to meet customers' needs more effectively.

2. Address problems at their source

Part of being a successful operations manager is solving problems and eliminating delays in production processes. To provide lasting solutions, operational supervisors should also identify the source of an issue rather than just handling the symptoms. Solving problems at their source allows operations managers to make long-term changes that prevent similar issues from arising in the future. Effectively eliminating issues early on helps companies to grow and develop without setbacks.

3. Invest in new technology

The popularization and development of digital technology have significantly impacted how businesses function in modern society. Operational supervision now involves using computers and digitally controlled machines to carry out administrative and product-oriented tasks. To help the operations supervisors maximize their workplace's potential, investments in the latest technological tools are necessary. Introducing machines that can automate simple tasks can increase the profits and help the contractor to stand out from competitors.

4. Simplify processes

To automate a process, it must first be made as simple as possible. Streamlining processes involves considering each individual step and determining if all the tasks are being completed as efficiently as possible. Simplifying processes allows operations managers to eliminate delays and reduce the waste of time and resources. Assessing processes and innovating ideas for improvement should be the constant pursuit of an effective operations manager.

5. Communicate effectively

Efficiency often relies on the effectiveness of a team's communication. Employers should be able to clearly communicate their expectations and goals to their operational supervision professionals. Similarly, the operations supervisor must also be able to instruct, guide and correct employees well. Effective communication allows all parties to work together without misunderstanding or delays.

3.2 Condition monitoring

The procedure of "Condition monitoring" is defined as the measuring of specific equipment parameters, such as vibrations in a machine, its temperature, or the condition of its oil, taking note of any significant changes that could be indicative of an impending failure. Continuously monitoring the condition of equipment and taking note of any irregularities that would normally shorten an asset's lifespan allows maintenance or other preventive actions to be scheduled to address the issue(s) before they develop into more serious failures.

Both the techniques and the technologies of condition monitoring shall allow the energy expert /

system designer to acknowledge / “listen to” the symptoms of poor equipment health. The condition monitoring procedure offers to the supervisor an early warning signal of a potential or impending asset or component failure before this actually happens. Some of the most popular techniques include:

- ✓ Vibration analysis
- ✓ Infrared thermography
- ✓ Oil analysis
- ✓ Ultrasound
- ✓ Motor current signature analysis.

A condition monitoring engineer is often likened to a doctor of assets. He may be able of listening to the “heartbeat” of the asset (vibration analysis), to take the bodily temperature (infrared thermography), and to take blood samples (oil analysis). All this helps to detect and diagnose impending failures or actual partial failures and then to extend the person’s or asset’s life cycle.

Traditionally, these techniques have been deployed manually: a technician or engineer walking from machine to machine with handheld data collectors or instruments and taking measurements manually every few weeks. He or she would then have to upload data to standalone PCs and report on the findings or even wait for analysis reports back from 3rd party service providers.

It is very important for the engineer/energy expert, holding the role of the project supervisor to try to be proactive and deploy a condition monitoring strategy, since this way arises the possibility of measuring the deterioration of rotating, reciprocating, and static assets of the water – energy system. Here are some common examples of the many asset problems condition monitoring can highlight:

- ✓ Worn bearings
- ✓ Pump cavitation
- ✓ Asset to asset misalignment
- ✓ Gear teeth wear
- ✓ External gearbox contamination
- ✓ Structural cracks in pipes or foundations
- ✓ Lack of lubrication
- ✓ Poor electrical connections
- ✓ Failing electrical components
- ✓ Deteriorated motor insulation.

Condition monitoring allows the supervisor to understand the failure modes and failure mechanisms of the critical asset base. And that’s valuable data and information for business intelligence and operational efficiency. But condition monitoring is more than that. It isn’t only useful for highlighting impending failure.

3.3 Condition Based Maintenance and Performance

After the condition monitoring procedure has been successfully completed, and most possibly information has been gathered that after the installation/commissioning and a period of reliable, stable operation, potential problems might arise in the equipment operation, another step has to be followed. A phase during which this very useful information can and must be efficiently used for the benefit of the entire system: it can be used to perform condition-based maintenance (CBM).

The Condition Based Performance is officially determined as: “An equipment maintenance strategy based on measuring the condition of equipment against known standards in order to assess whether it will fail during some future period and taking appropriate action to avoid the consequences of that failure. The condition of the equipment could be measured using condition monitoring, statistical process control, equipment performance or through the use of human senses. The terms condition based maintenance (CBM), on-condition maintenance and predictive maintenance (PdM) can be used interchangeably”.

The CBM is a subset of the preventive maintenance (PM). But whereas the traditional PM procedure focusses on replacing or overhauling components or assets that wear out on a time or usage basis, CBM allows us to perform data-driven maintenance on assets that suffer wear out and random failure modes. This means that there is reference made to maintenance when it is genuinely and actually needed. The other forms of PM – if not set up correctly – can lead to replacing components that are still in a good, operable condition, i.e. over-maintaining and thus leading to wasting valuable resources.

Some of the most obvious and critical benefits for the feasibility of a system imposed to condition based maintenance are presented below:

- ✓ Higher asset availability
- ✓ Increased production output
- ✓ Less unplanned downtime
- ✓ Reduced maintenance and life cycle costs
- ✓ Optimized human resources
- ✓ Reduced invasive PMs (overhauls and component replacements)
- ✓ Improved maintenance planning and scheduling
- ✓ Better spares forecasting
- ✓ Root cause analysis information for defect elimination

The implementation of a condition monitoring during the entire supervision of a water – energy project and especially in case that the former constitutes a central theme of the maintenance strategy, consists of a step towards an added value to the lifetime of the system, in parallel amounting to reduced risk, lower production costs and increased asset and operational performance: the three central principals of professional, modern asset management.

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SELF-ASSESSMENT QUESTIONS FOR MODULE 2

1.	**The person to whom the site supervisor reports on a regular basis is:**	
	a. the project manager	
	b. the project supervisor	
	c. the qualified person	√
	d. the contract administrator	
2.	**Select all the activities that belong to the Pre-commissioning phase (*please choose all the correct ones*):**	
	a. Electro-mechanical and mechanical equipment	√
	b. HV electrical works	√
	c. Electrical equipment	√
	d. Wet-Commissioning	
3.	**Indicate which of the below belong to the main tasks of the CA:**	
	a. General administration	√
	b. Keeping of records	√
	c. Conducting essential tests on building materials	
	d. Reporting to the clients	√
4.	**Indicate the correct chronological order of the main steps of the commissioning planning:**	
	a. Prepare commissioning specification section for bidding documents	4
	b. Define owner's systems performance acceptance criteria	2
	c. Prepare a Commissioning Plan	1
	d. Review design documents for compliance with acceptance criteria	3
5.	**The Wet-Commissioning procedure:**	
	a. relates to the demonstration that the upgraded asset and all associated components integrate and operate as intended.	√
	b. includes dry tests on equipment and systems to confirm initial configurations, fail safes and operation.	
	c. is used to determine the control system operates in accordance with the FDS and involves the initial setting of control loops.	
6.	**The key stages of the SAT are:**	
	a. The Pre-SAT and the SAT.	
	b. The SAT and the Operational Test.	
	c. The Pre-SAT, the SAT and the Operational Test	√
7.	**The strategies to maximize the potential of operational supervision are (*choose the correct answer*):**	
	a. Prioritize the customer, Address problems at their source, Invest in new technology, Simplify processes, Communicate effectively.	√
	b. Prioritize the customer, Address problems at their source, update all project documentation, Communicate effectively.	
	c. Address problems at their source, Invest in new technology, prove the correct operation of all components	

8.	**The Condition Based Maintenance…**	
	a. follows the condition monitoring procedure.	√
	b. is prior to the condition monitoring procedure.	
9.	**The Integrated Asset Commissioning is:**	
	a. the phase in which all newly commissioned and existing systems are integrated together to be tested and operated in their final process arrangement.	√
	b. the period of operation with process fluids immediately following cut-over or seeding in which equipment and control setting are adjusted and tests conducted for a period to ensure the Components operate as intended.	
10.	**Which of the below statement(s) is /are true?:**	
	a. The SS should adhere to the site inspection schedule as prepared.	√
	b. The SS must safeguard construction works to meet design specification	
	c. The CA deals with the financial matters	√

MODULE 3: WATER MEASUREMENTS AND WATER-ENERGY NEXUS

SUMMARY

The measuring of water systems is essential to effectively improve water-energy efficiency in buildings. Through measuring, it is possible to make an identification and diagnosis of water-energy consumptions, and thus provide improvement efficiency measures. The goal of measuring or monitoring is to provide information so that expert technicians or auditors can develop action plans according to the collected data. With the advances in metering technology and lower prices, the implementation of these systems has increased which is driving management improvements in the water-energy systems across public and private buildings. Monitoring may be important when performing water audits or to test a specific equipment or installation.

The use of correct measurement and verification methodologies is the next step for building owners to develop actions plans that meet both energy and water goals, achieve financial savings and improve building operations. International Performance Measurement and Verification Protocol (IPMVP) is one of the most used protocol for measurement and verification procedures and can be used by building managers to improve building management. It is also a powerful tool and ally of expert technicians and auditors that develop actions plans and need to precisely track the savings obtained with the project implementation.

Module 3 “Water measurements and water-energy nexus” is the third of four Water Efficiency Expert (WEE) Modules and that the WATTer Skills project has produced. It integrates four Units:

Unit 1: Collection, verification and analysis procedure definition for field data related to water-energy use

Unit 2: Determination of baselines for water-energy use or demand assessment

Unit 3: Identification and prioritization of water-energy saving measures

Unit 4: Monitoring of the cost benefits and impacts from applying water-energy saving measures.

Unit 1 of Module 3 provides the principles of the procedures for definition of the collection, verification and analysis of field data related to water-energy use. This will be useful for the identification of the necessary data inputs for studying water-energy profiles with respect to different parameters, and for the elaboration of fact sheets to collect real data, improving the ability to identify water-energy performance indicators based on field data.

Unit 2 of Module 3 provides the procedures to determine water and energy baselines for water-energy use or demand assessment. This may useful to improve knowledge for quantifying water and energy consumption profiles, identifying the water-energy baselines and provide guidelines for the identification of water-energy efficiency measures and promotion of an efficient behaviour. Unit 2 also provides the definition of procedures and requirements for comparison of water-energy data measurements and of regulations and standards (local, national, international) applicable to the project, before and after commissioning. The aim is to enhance abilities to identify the water-energy profiles and baselines based on field data, and to identify water-energy performance indicators and

establish comparisons.

Unit 3 of Module 3 describes the methods used for the identification and prioritization of water-energy saving measures aiming at defining the procedures for the assessment of field data derived in the necessary water-energy balances in buildings. Thus, it provides capacitation for the identification of alternative water-energy saving measures, as well as to suggest and identify good practices in water-energy efficient usage.

Unit 4 of Module 3 describes the methods of monitoring cost-benefits and impacts from applying water-energy saving measures in order to improve knowledge for defining procedures for monitoring water-energy data and cost-benefit analysis of alternative water-energy saving measures. The goal is to enhance abilities to perform cost-benefit analysis and monitor the impacts of applied water-energy saving measures.

Unit 1: Collection, verification and analysis procedure definition for field data related to water-energy use

General description

Water measurements are essential when performing building diagnosis as water consumption is distributed over several systems and spaces across the building. Measurements provide a reliable source of data that can be used for improving building management and elaborate efficiency measures.

In this unit, the principles of the procedures for definition of the collection, verification and analysis of field data related to water-energy use are presented. The scope is to provide methods for the identification of the necessary data inputs for studying water-energy profiles with respect to different parameters, to show how to elaborate fact sheets for collection of real data and to identify water-energy performance indicators based on field data.

Scope – Expected results

At the end of this Unit, the candidate should be able to:

- identify the necessary data inputs for studying water-energy profiles;
- elaborate fact sheets for the collection of real data;
- make the verification of field data related to water-energy use;
- identify the water-energy performance indicators based on field data.

This Unit is constituted by 2 lessons:

LO1: Collection of field data related to water-energy use

LO2: Analysis of field data related to water-energy use

Key words / basic terminology

Water network, consumer behaviour, water fixtures, water demand, inspection and auditing.

1.1 Collection of field data related to water-energy use

The use of monitoring equipment to analyse water and energy consumption of buildings, and other related variables, is important to the optimization of water and energy consumption and building operation. While meters do not provide any water or energy saving themselves, information brought through data interpretation during its implementation supports decision-making regarding the identification of actions plans and management improvement.

For expert technicians or auditors, the data collected with the meters may help in processes such as verification of utility bills, comparing utility rates, allocation of cost to tenants, demand response schemes, measurement and verification in performance contracts, benchmarking use of water and energy, identifying inefficiencies and retrofit opportunities, tracking budgets for improvement plans and water and energy usage. Moreover, the implementation of meters aims to reduce water and energy use and water and energy costs, as well as to improve building and equipment performance.

1.1.1 Identify the necessary data inputs for studying water-energy profiles

One of the expert technician or auditor main tasks is to characterize the case study building. For that purpose, one should be able to identify the data to be gathered during the audit in order to have a detailed analysis. To achieve this, the expert technician or auditor will perform a checklist of items to be monitored or characterized during the visit to the installation or audit, according to the typology of the building. In the case there is a preparatory site visit, there should be a validation of the data priorities identified previously with on-site observations. During the audit, the preliminary work will provide useful information and will reduce audit time.

The following topics include some of the inputs that should be considered by expert technician or auditor for the water-energy nexus audit:

- Water and energy daily needs
    - Water consumption – continuously measured by flowmeters, either located at specific locations (such as the house entry or the basement), usually in cubic meters. Graduated measuring equipment may be used to discrete sampling at fixtures, etc.
    - Energy load – The international system unit is the joule, but it is often measured in kilowatt hour. Temporary energy analysers or permanent meters are used to measure energy load.
    - User profile – The demand profile corresponds to the behaviour consumption behaviour pattern, related to building end-users.

- Elements on the water distribution networks
    - Potable water
        - Pipes – component used for water passage, securing interconnections between fundamental parts in the distribution network that can be analysed for potential leaks, with specific dimensioning characteristics, material and accessories, adequate to the potable water.
        - Valves – devices used to allow or stop water flow or isolate specific component during any intervention.

    - Fixtures – terminal water uses including faucets, flushing or showerheads, should be characterized as they allow to estimate consumption and perform consumption breakdowns (further explained in Unit 3).
    - Appliances– equipment that uses water (and energy) and that may be used to cloth or dish washing, etc.

- Reused water
    - Pipes – as pipes in potable water, but with specific dimensioning characteristics, material and accessories, adequate to the fluid that is being collected or reused[1].
    - Valves – as valves in potable water, but specific to the fluid that is being collected or reused.

In buildings with reused water networks, water safety should accompany the installation and be carefully designed to guarantee no interconnections between the reused water network and that of public supply.

To adequately monitor the mains water usages, it is first necessary to do the characterization of each system correctly, so that the adequate meter can be installed during the audit. Choosing specific metering options dependent on many factors including the following:

- Temperature – cold or hot water circuits need to be monitored at specific temperature ranges, or there can be malfunction or data misinterpretation. Temperatures above 25°C are considered domestic hot water so meters need to be adequate.
- Pressure – it is important to compare different operational flows in fixtures, as well as to determine the building pressure range. Balanced flow pressure is important to guarantee balanced water consumption and prevent pipe degradation or long water retention times.
- Flow – the network capacity is important to guarantee minimal and maximum operational conditions, for the guarantee of adequate water quantities provided to the consumers.
- Velocity – flow velocity should meet regulation requirements and be adequate to guarantee good system performance (minimisation of noise, extended residence times, material deposition and pipe deterioration).

1.1.2 Elaborate fact sheets for the collection of real data

One important factor that should be planned before undergoing monitoring is to prepare a checklist for data collection and measuring. The checklist allows the expert technician or auditor good preparation of the monitoring procedure and avoid missing points that should be verified. The checklist allows to take quick notes, on-field, thus facilitating the characterization of the building and reduction of monitoring/auditing times.

A general checklist should be applicable to several building typologies, but tailored approaches need to be conducted to cover data and site specifications. The checklist should also work as a technical data sheet to facilitate the collection of data during the monitoring step or audit. Some of the gathered data include:

[1] Reused water pipes need to be carefully identified and no possible interconnections can take place with the public water network. This should be carefully implemented and licensed by the water utility supplier.

- Building Identification (location, tenant, contact person, etc.)
- Background Information (typology, occupants, area, divisions, etc.)
- Construction details (building envelope, windows, blueprint, etc.)
- Billing Information (overall consumptions, costs, etc.)
- Equipment characterization (fixtures, appliances, lighting, DHW systems, etc.)
- Space characterization (sub-metering data, equipment allocated per space, etc.)
- Consumer profile/comfort characterization (routines, equipment handling practices, set-points, etc.)
- Maintenance type and number of maintenance actions performed and entries of date when they occurred, etc.).

The ex-ante analysis, or pre-monitoring phase, is fundamental to have a successful and quick monitoring process. This stage typically consists in the preparation of the monitoring procedure and, if applicable, the audit (elaboration of checklist and methodology for conducting the audit), including the information request to the building manager and the analysis of energy-water bills and other data provided.

The ex-ante analysis of the data consists in extracting results from the data requested to the clients. The goal is to plan the audit, especially the prioritization of reading points and equipment characterization. Water and energy bills are important elements for an initial baseline analysis. This could also be used for benchmarking purposes that will provide the expert technician or auditor with information regarding on a specific building compares to similar ones in terms of water and energy consumption.

The preparatory site visit is used to understand the current status of the building and to perform an initial major evaluation. This enables the auditor to prepare the audit in more detail and to start planning retrofit needs, action plans and saving potentials. This may also be important to motivate clients towards the outcomes of undergoing building monitoring and evaluation.

1.2 Analysis of field data related to water-energy use

The monitoring of the building is an analysis that should provide better understanding of resource consumption associated with building use/activities, map the consumption use patterns and detail all relevant characteristics. The data gathered during monitoring may help to provide consumers / customers with specific knowledge about where and how water and energy are used in the building as well as the saving opportunities.

Monitoring of the building may be an important tool to raise awareness for building users to change practices that contribute towards an efficient use of resources by positive reinforcing the value of behaviour impact. The quality of the monitoring study is critical to site prospection and auditing, firstly dependent on the data that can be collected during site survey and information provided by the consumer/customer.

1.2.1 Verification of field data related to water-energy use

Meters are used to provide an output through meter intersection. The goal is to provide data that will improve building management and the definition of an efficiency action plan. Metering can vary according to the relevance of each device in the overall system. Long-term measurements are important to get reasonable amounts of data and with good accuracy but should not be randomly applied as being more expensive than discrete or short-term measurements. Also, when deciding for high-frequency or long-term measurements, the time needed to data interpretation should be guaranteed.

To gather all the essential data, the following list details some of the common equipment used:

- **Flowmeters – volumetric water meters** can be divided in three categories: mechanical, differential pressure and velocity (e.g., electromagnetic, ultrasonic). Of these, the mechanical (i.e. positive displacement meters) are the ones that measure directly water flow. The other two measure other variables/physical characteristics and indirectly calculate the flow.
  - Mechanical meters (positive displacement meter) measure the fluid that occupies a given space over a pre-set time. These meters are typically used in residencies, as they work better for low flow rates. The most common example of positive displacement meter is the nutating disc meter (Figure 1.1) that has a disc that is moved is the water flow, this disc is attached to a magnet that registers its rotation. As the space inside the disc is previously known it is possible to transform the rotation into a water flow.
  - Differential pressure meters have a restrictive section and the pressure differential is assessed upstream and in or after the restrictive section, which is proportional to the flow rate according to the fluid characteristics. Common meters are the orifice flowmeter or the venturi meter (Figure 1.2).
  - Velocity meters – Several variations of velocity meters are used, the turbine flow meter is measures the fluid speed as it rotates a turbine, the vortex-shedding flow meter measures disturbances in the flow after being shredded by a stationary body and the disturbances are proportional to the flow rate and the ultrasonic flow meters (Figure 1.3) that use ultrasonic signals with the principle that the sound travels faster in the direction of the flow.

Figure 1.1: Nutating disk flowmeter

[Author: F Silva]

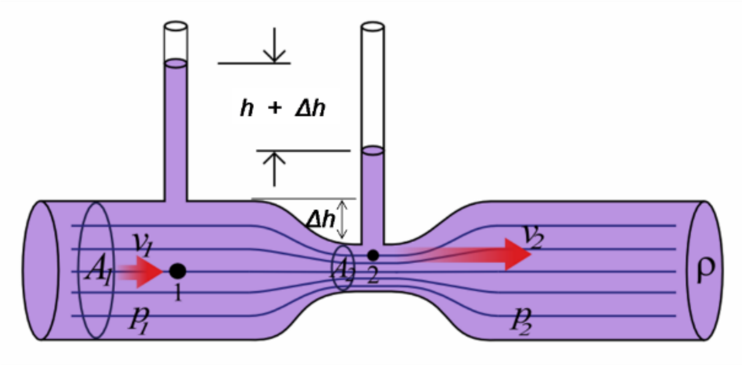

Figure 1.2: Working principle of venturi flowmeter

[Image by HappyApple, licensed under CC BY-SA– Creative Commons]

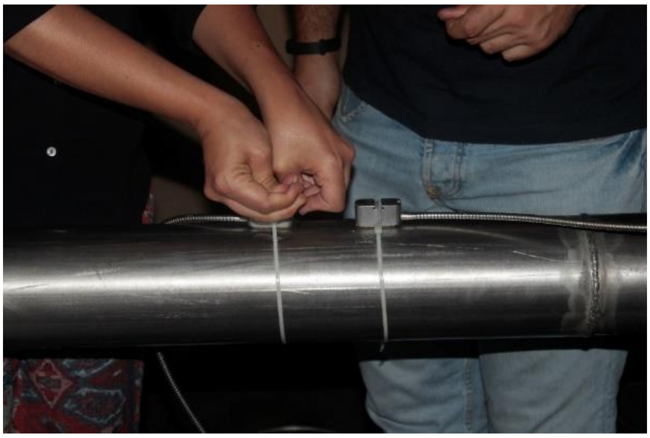

Figure 1.3: Installation of ultrasonic flowmeter transducers/receivers

[Author: F Silva]

- **Water meters** – devices which record on a counter or dial the flow of water which passes through it. Water meters can be used specifically for water billing purposes. Flowmeters can be used as water meters, when the fluid being measured is water. Water meter can be of single-jet, multiple-jet, turbine type or a combination of them.
  - Single-jet water meters - the operating principle is based on the direct incidence of a single jet on a rotating turbine housed inside the body or casing of the measuring device, usually made of brass with a consumption totalizer connected by a mechanical or magnetic coupling to the turbine. The rotation speed of the turbine depends on the impact speed of the water jet.
  - Multiple-jet water meter – in multi-jet meters the water hits the turbine at the entire periphery of the chamber, due to a chamber that distributes the water in several circularly distributed jets around the turbine. This provides a balanced water distribution contributing to longer durability of the meter and securing also better performance within small flow range.
  - Turbine type – The rotary movement of the turbine is transmitted by a magnetic coupling to a hermetically sealed register which indicates the water flow and the accumulated volume. The register is kept absolutely isolated from water and impurities, which protects it from corrosion.

- **Energy meters** – depending on the type of energy in use, multiple different metering methods can occur. Being two important residential forms of energy, this unit focus on two of the most common types of energy: Electricity and Natural Gas

- Natural gas – transported in liquid form, the meters used are like those use for water measurements such as the positive displacement, differential pressure and velocity meters. Slight differences can be found between the sensors as natural gas networks usually have increased pressure compared to water networks inside buildings and the fluids have different characteristics, such as density, that affect the measurement so the sensor must be tuned for the specific fluid.
- Electricity – more complex meters can analyse power quality and harmonics while the simplest meters only analyse current. The most common types of electricity meters include the mechanical meters, electro-mechanical meters or solid-state meters (Figure 1.4).

Figure 1.4: Residential smart electrical meter

[Author: F Silva]

- **Pressure meters** – usually called pressure gauges (Figure 1.5) that are typically installed in these networks to evaluate possible problems in the system. Gauges can be used be to evaluate system overpressure or under-pressure, where overpressure can be related with explosion, rupture or system failure and under-pressure may be associated with leaks or problems in the pumping system. Pressure metering can also be used to evaluate other parameters such as the flow rate due to the relation between variables, as used in the differential pressure flow rate meters.

Figure 1.5: Pressure gauge in a domestic hot water system

[Author: F Silva]

- **Temperature meters** – used in water-energy audits to read and register the thermal energy of a fluid based on its temperature gradient. These sensors can also be used for maintenance purposes to avoid overheating or freezing. Typically, water networks have valves where a temperature probe can be inserted and measure the temperature directly. In other cases, external contact probes (Figure 1.6) are attached to the pipes and measure the temperature via heat conduction through the pipe.

Figure 1.6: Thermocouple connection for pipes

[Photo by Z22, licensed under CC BY-SA – Creative Commons]

While most of the equipment previously mentioned is pre-set with the parameters for the desired effect, portable equipment may need to be configured as it can be used in many different scenarios. For portable electrical analyser, the process usually includes the connection of the tension cables in parallel with the existing circuit and the connection of current clamps. For the current clamps (Figure 1.7) it is important to remember that one clamp should be used per cable. It is also important to remember to always match tension and current measuring.

Figure 1.7: Two current clamps installed in an electric board

[Author: F Silva]

Portable flow meters are usually ultrasonic. These meters can be installed by fixing the transducers / receivers onto the pipe. For accurate results the transducers/receivers must not be fixed onto the pipe near a curve of any obstacle (the minimum distance required to any of these singularities is about 10xDN).

Metrology - the science that studies measurements – is directly related to monitoring and metering, as these may be key for building consumption characterization. Metrology includes parametrization and enabling of equipment standardisation. To guarantee this, calibration essays should be used.

The international system of units is used around the world as the base language to communicate science, technology, industry and trade. The system has established ca. seven base units that can be important in water-energy audits, to have standards such as:

- Temperature – Kelvin [K] – Common: Celsius [°C]
- Pressure – Pascal [Pa] – Common: Bar [bar]
- Flow Rate – Cubic meters per second [m^3/s]
- Velocity – Meters per second [m/s]
- Specific heat – Joule per Kelvin Kilogram [J/(K.kg)]
- Power – Watt [W]
- Water quantity – Cubic meter [m^3]
- Energy load – Joule [J] – Common: Kilowatt hour [kWh]

Due to several factors, meters can provide inaccurate readings, so expert technicians and auditors should be capable of identifying these inaccuracies and proceed to fix them. Analysing data with a critical view may be enough for an experienced technician to find errors in the monitored data, but good practice is to undergo confirmation to all verifications by using a calibrated meter.

If it is confirmed that the meter is malfunctioning, it should be sent to the manufacturer or a calibration company to be fixed or undergo a calibration essay.

- Calibration essays – To reduce inaccuracies and uncertainty, it is important to periodically send meters for calibration. Track of calibration should be kept guaranteeing consistent calibration methods amongst different stakeholders.
- Calibration frequency – manufacturers should provide a recommendation for each equipment relating to the period between calibrations. In case of data inconsistencies or accident, calibrations may be performed earlier.

Installation procedures for measuring equipment

The measuring instruments shall be placed by a competent and, if possible, familiarised with the installation professional, who may not be a member of the team of auditors. The type and the positioning in the circuit of the meters and probes are elements of greater importance in the installation of this equipment. Another important aspect is related to the non-interruption of the water supply, using non-intrusive meters.

Placing this equipment on the circuit requires some care:

- Respect the recommendations of the equipment supplier;
- Position the flow meter or any meter between two section valves to allow its repair/replacement whenever justified;
- Have a filter placed before the meter to reduce the deposition of sediments in the water inside the flow meter;
- Respect the distances between the last accessory and the flow meter, the minimum recommended value being 10xDN of the pipe;
- Use preferably the coldest pipe of the circuit for its positioning; in the case of domestic hot water (DHW) pipe, if the hot water system has a water tank, position the flowmeter in the cold supply pipe of the tanks instead of the hot water delivery pipe;
- When using temperature probes for energy integrators, they should be positioned in counter-current to the direction of flow, seeking that their end reaches the centre of the pipe;
- All wiring of the probes should be placed in protective sheaths to reduce potential impacts and consequent inoperability;
- During measurement, the meter must be filled with water;
- Considering that the probes of energy integrated meters are usually supplied in previously calibrated pairs (hot and cold), the probes should only be replaced by equivalent ones.

While the monitoring step is fundamental for expert technicians and auditors to collect the essential data that will allow them to fully characterize the building under study, the pre and after audit assume equal importance in the overall characterization process. The latter will provide the starting point to baseline characterisation and the ex-ante evaluation will provide strategic information used to plan the metering points, the extent of the monitoring or audit and the approach for measurement and verification.

After the monitoring period, the data collection can be finally analysed, and the action plan is concluded based on the calculations performed. At this stage, the efficiency measures should be thoroughly detailed, including technical and economical specifications, and all foundations should be laid for the monitoring and verification of the proposed savings after the efficiency project implementation.

1.2.2 Identification of water-energy performance indicators based on field data

The breakdown of the overall estimations of the daily water usage in buildings can be estimated by water-point, through fixture/equipment specifications or through measuring, ideally considering equal testing conditions (e.g., pressure and temperature). The indicators that can be generated by on-field performed measurements that should include water and energy consumption in the different building component groups:

- Water sources and infrastructure – alternative sources of water and the water network distribution infrastructure;
- Outdoor uses – exterior area property of the building/household owner/user, including garden, pool, garage, roof;
- Water fixtures – taps, toilets, shower heads or other types of fixtures present;
- Water appliances – washing machines and dishwashers;
- Domestic hot water production – thermal energy production equipment and domestic hot water network.

Likewise, in a building/household, the set of measuring equipment that may be included to assess water efficiency performance evaluation may be as follows:

- Flowmeter – adequate to measure the flow in a fixture or pipe. Measuring equipment specifications should consider a representative flow length, allowing the possibility of measuring low and high flows in common fixture households. Resolution should be adequate to measure flow in litres per second.
- Calibrated volume – adequate to measure the capacity of a toilet flush. It may be used as a flowmeter together with a time watch. Resolution should be adequate to measure litres.
- Ruler or dimension reader – measuring equipment of dimensions to calculate areas for gardening, garage, etc. Resolution should be adequate to measure cm.
- Thermometer – adequate to measure water temperature. Measuring equipment specifications should consider the need of doing rapid reads and it should not be easily breakable. Resolution should be adequate to measure cold and hot water temperatures of ca. 0-100°C.
- Pressure reader – adequate to measure flow pressure in a fixture or pipe. Resolution should be adequate to measure pressure of ca. 1-10 bar.
- Timer – adequate to measure time and assess flow rate together with volume measurements. Resolution should be adequate to measure seconds.
- Thermography – adequate to perform thermal imaging inspection for the detection of temperature differences in distribution pipes, useful to detect water losses or pipe scaling. Equipment should be adequate to measure distribution water pipes.

In the definition of indicators, it is important to address technical performance, financial, environment and quality strategies/approaches. Similarly, it is important to assess the consumption profile breakdown, as well as the aimed targets (e.g., defined by the owner/consumer), legislation or other relevant criteria. The following table shows some examples of indicators that can be applied at the overall building or by component group levels.

Table 1.1: Water-energy efficiency indicators (examples)

Targeted water uses	Examples of indicators
Overall building	– Energy consumption per person (kWh/inhabitant) – Water reuse per person (litres/ inhabitant) – Annual energy consumption expenditure (€/year/inhabitant) – Annual water consumption expenditure (€/year/inhabitant)
Component group	– Hot water consumption per area (litres/m^2) – Hot water consumption per day per inhabitant (litres/day/inhabitant)

In order to make an evaluation of the indicators, their definition should be accompanied by the supported measurements, measured variables, reference values and evaluation judgment, based on the application of reference values to the indicator result. With a defined baseline, the indicator evolution and target may support the implementation of water and energy efficiency measures.

Table 1.2: Water-energy efficiency indicators assessment

Target water uses	On field measurements	Measured variables	Indicators	Reference values	Evaluation judgment
Overall building	(to fill in)	(to fill in)	(to be calculated based on the measured/known variables)	(defined based on legislation, etc.)	(to be defined based on the result and the reference values)
Component group	(to fill in)	(to fill in)	(to be calculated based on the measured/known variables)	(defined based on legislation, etc.)	(to be defined based on the result and the reference values)

Unit 2: Determination of baselines for water-energy use or demand assessment

General description

Water and energy consumption vary according to many factors, making it difficult to predict future consumptions. The definition of a baseline of consumption may allow to track performance improvements, establish comparisons based on reference values and provide implementation measured.

In this unit of Module 3, the methods for determining a consumption baseline for water-energy use or demand assessment will be provided focusing on the identification regulations and standards (local, national, international) applicable to each project, the identification of valid variables for baselining and the definition of procedures for comparison of field data.

Scope – Expected results

At the end of this Unit, the candidate should be able to make:

- Quantification of water and energy consumption profiles;
- Identification of the water-energy baseline based on field data;
- Regulations and standards (local, national, international) applicable to the project;
- Comparison of water and energy use requirements with the reference values of building regulations.

This Unit is constituted by 2 lessons:

LO1: Assessment of water and energy consumption profiles

LO2: Using reference values of water-energy use from building regulations and standards

Key words / basic terminology

Baseline consumption, sampling and monitoring, regulations and standards.

2.1 Assessment of water and energy consumption profiles

Measurement and verification procedures tend to vary due to the occurring different conditions in buildings while international standards promote the use of common and easily understandable methodologies. For end-users, the use of standard processes increases their trust in the transparency and quality of the work developed, thus providing the possibility of benchmarking or brought of conclusions to the obtained monitoring results.

2.1.1 Quantification and baseline profiles

Household water systems may be comprised of the following fundamental component groups: water sources and infrastructure, outdoor uses, water fixtures, water appliances and domestic hot water production. During the post monitoring phase, it is important to verify that all data obtained allows for building/household characterisation. This phase usually consists in monitored data processing, breakdown of consumption and the establishment of performance indicators. To do so, the expert technician or auditor should apply statistical methods, data interpretation and validation.

Breakdown of consumption and the definition of performance indicators are used to benchmarking purposes, serving both auditors and clients for the implementation and tracking of results related to efficiency action plans. For the quantification of consumption profiles, the sampling approach done by the time of the preliminary study should be revisited (see Figure 2.1, with an example provided in Figure 2.2), to guarantee that the initial assumptions and targeted required information are adequately measured and can be obtained.

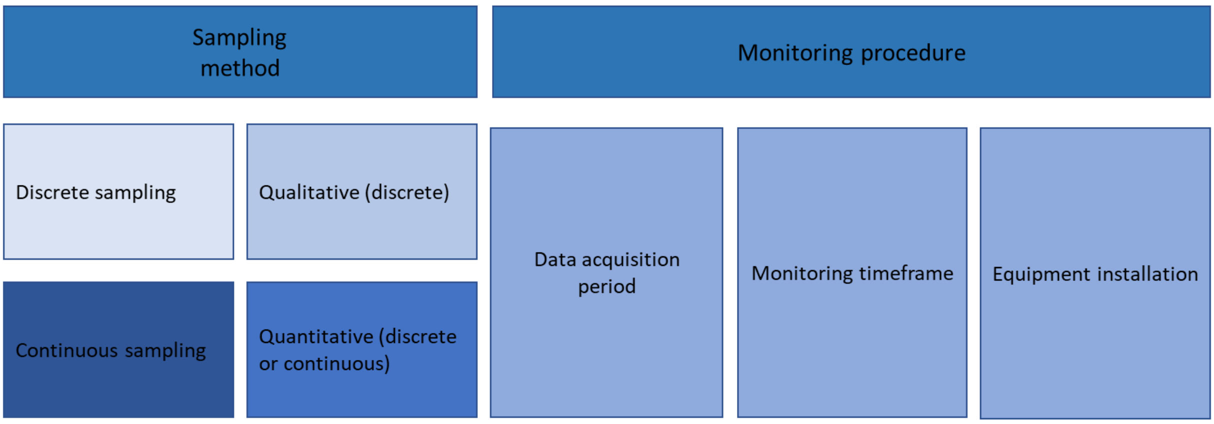

Figure 2.1: Sampling approach: sampling method and monitoring procedure

Variable data is highly valuable for measurement and verification, with some protocols requiring a minimum period of measurements and minimum acquisition rate. In the analysis of performance, being the energy and water consumption the basis for the analysis, it is possible to divide all variable data collected into two categories: dependent variables and independent variables.

Independent variables may be used to normalise water and energy consumption. Examples of common independent variables are:

- Weather variables (outside temperature; solar radiation; rainfall; etc.)

- Operating hours and vacancy rates
- Occupancy.

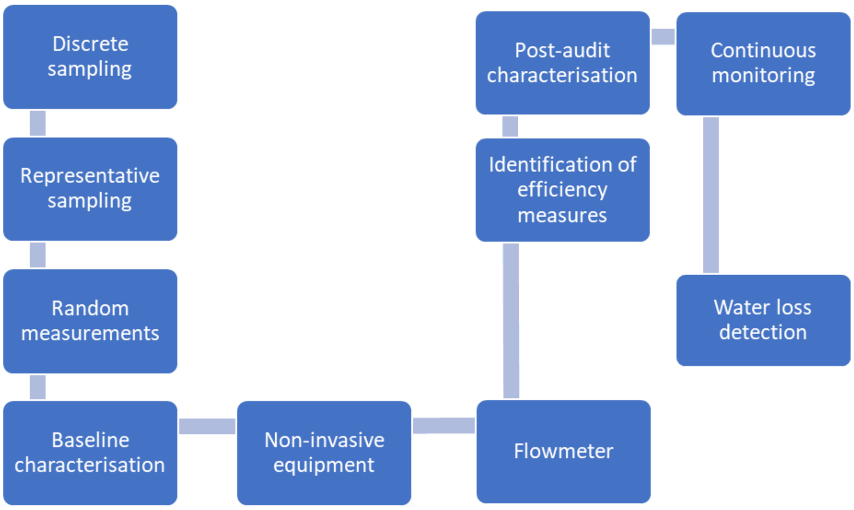

Figure 2.2: Example of a sampling approach

Weather variables are important to assess the real impact of efficiency measures targeting rainwater harvesting systems, irrigation systems, heating ventilation and air conditioning (HVAC) systems, lighting systems amongst others. Operating hours and vacancy rates can be used when detailed occupancy is lacking. Occupancy changes in a building have a high impact in the energy and water consumption so this is an important parameter to assess in all buildings.

Non-variable data mainly assists in the building characterization and in planning the efficiency measures. When the expert technician or auditor has identified the variables to characterize the baseline then it is necessary to use a forecasting method to have a reference for future consumption levels.

Regression analysis may be used to forecast conditions based on past data, considering the existence of a relation between a dependent and independent variable. In the existence of multi independent values, the expert technician or auditor may need to apply multi-linear regression. Other more sophisticated forecasting methods may be used.

2.1.2 International Performance Measurement and Verification Protocol

A widely known approach for operators to assess and improve facility performance is the International Performance Measurement and Verification Protocol (IPMVP). Although widely used in the energy sector, to assess energy savings, it may as well be used for water savings. IPMVP presents the basis for good measurement and verification (M&V) process while allowing customization for each project that suit its objectives in terms of energy and water savings.

IPMVP was published with the goal to increase investment in the energy and water efficiency market and aims to provide an accurate way to estimate the savings obtained with an efficiency project. The accuracy is essential from business perspective, with implications on the return of investment of the financing entity.

IPMVP also aims to provide consistency amongst efficiency projects and to focus on critical aspects of these project while less relevant details can often be estimated in a conservative way. Also, the transparency provided by standards like IPMVP one of the most important features to build customer trust. One of the strengths of the IPMVP standard is that it is customizable according to the boundary of the measurements performed and to the detail of the historical data available. This flexibility allows expert technicians and auditors to easily implement the standard regardless of the conditions of the building in analysis.

To enable this flexibility, IPMVP developed four different approaches to the M&V procedures. These are called Option A, Option B, Option C and Option D:

- Option A: the verification is based on a partial measurement of the equipment affected by the efficiency measures; parameters considered not critical can be estimated by the parties based on available data and calculations. Reporting period data must be short-term or continuous to detect consumption fluctuation.
- Option B: verification of an efficiency measure at the equipment level is based on full measurement, no estimative is possible contrasting with Option A. Reporting period data should be short-term or continuous, the same as Option A; in case of unavailable data proxies of use can be used to compute the results.
- Option C: savings are determined from utility meters or sub-meters to assess the performance of the entire building. Continuous measurements are required to avoid influence of parameters not targeted with the efficiency measures.
- Option D: results from the implementation of efficiency measures are determined using computer simulations. Real data is used to calibrate the simulation.

Regarding the measurement boundary, technical experts and auditors may opt for assessing the entire facility or just a portion of it, depending on the coverage of the efficiency measures planned for the building. In some cases, the period data required to build the baseline may be unavailable or unreliable so a different methodology may be used to overcome this issue.

Consumption profiles (Figure 2.3) may be assessed through a survey, where the owner/consumer provides information regarding the overall use of the building/household (e.g., in use, no use) and occupation (e.g., main/temporary, number of people), or through a complete set of measurements. This, rather than the survey, should include measurements targeting to retrieve the following information:

- Flushes - discharge volume, the number of uses per person per day, the number of uses per number of people per household and the technology in place (e.g., dual or single flush);
- Showers – flow, the time of use per person per day, the number of uses per people per household and the technology in place (e.g., water and air mix);
- Taps – flow, the time of use per person per day, the number of uses per people per household and the technology in place (e.g., water and air mix);
- Water appliances (washing machines) – volume per cycle and number of uses per people per household;
- Alternative water sources – availability (rainwater) and possible water reuse destinations (flushes, irrigation).

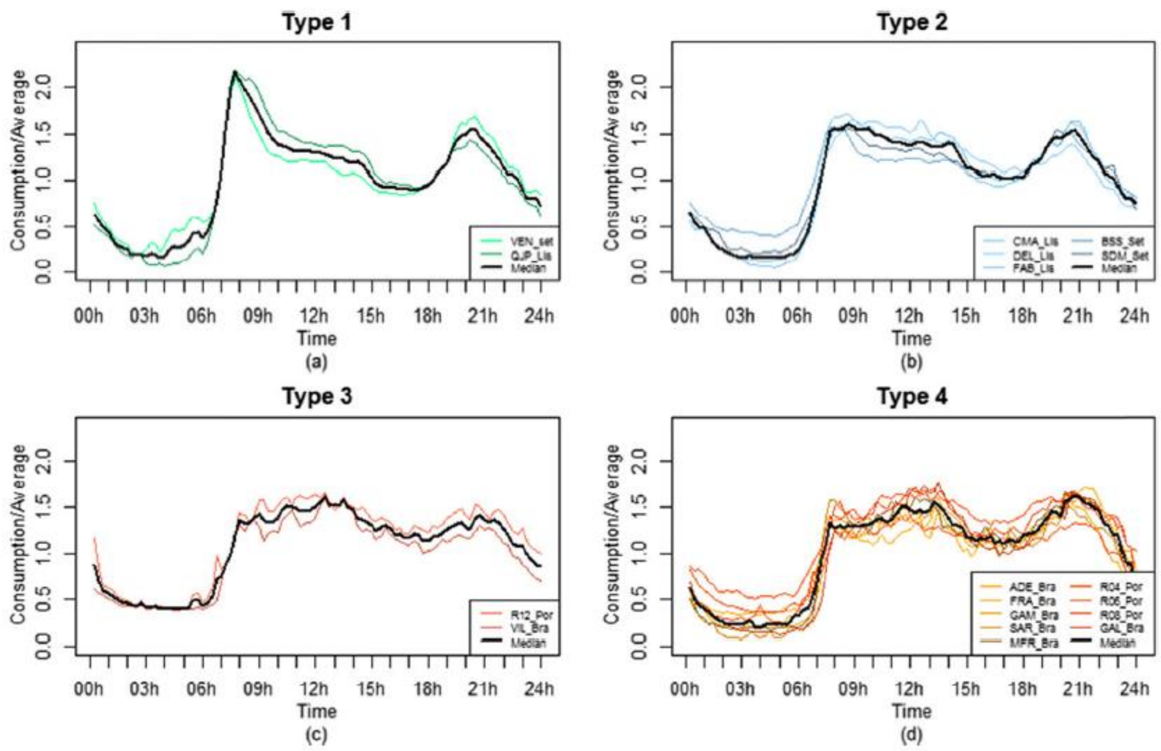

Figure 2.3: Variation in daily consumption patterns respective to different pattern types: 1) maximum value in the morning, 2) largest consumption during the day, 3) higher demand in the morning and lunch periods, 4) largest consumption at lunch and dinner

[Source: Loureiro et al., 2016]

2.2 Using reference values of water-energy use from building regulations and standards

The monitoring of the building/household baseline definition and efficiency measures implementation requires the expert technician and auditor to follow the existing regulations, standards and good practices. All the mandatory regulations and standards driven at a European or National level should be followed by the expert technician and auditor. In the absence of mandatory legislation and norms, good practices may be carefully followed, particularly, under the following specific topics:

- Water supply, water reuse and wastewater engineering;
- Service activities relating to drinking water systems and wastewater systems;
- Quality criteria for water supply;
- Product commissioning;
- Outdoor water uses (e.g., pool, irrigation);
- Eco-design and labelling.

Besides careful revision of the existing and applicable regulations and standards, the expert technician and auditor may need to consult or inform the water utility if the monitoring phase will have an impact in the system. All possible interconnections with the drinking water supply network should be avoided. The water utility should be involved in the process of revising the hydraulic project dimensioning and layout, particularly the possibility of having such interconnections. Reused water pipes need to be carefully identified and no possible interconnections can take place with the public water network. This should be carefully implemented and licensed by the water utility supplier.

Reference values are important to evaluate measurement results in monitoring or auditing. The evaluation consists in opposing the measured value considering the physical parameter in study (e.g., flow pressure or velocity) with regulations standards (e.g., minimal and maximum pressure or velocity). Reference values are not available to all the possible measured parameters but can be assessed with norms and good practices. The expert technician and auditor experience may be also useful when reference values are not shown in literature.

International regulations and standards in the water sector are of extreme importance to guarantee from source to transport, supply, distribution and consumption. The Water Framework directive establishes regulations for protection of water, including freshwater, groundwater and coastal waters, being transposed to the State Members, and represents the main instrument of the European Union with respect to water political management.

Also, the European Committee for Standardization develops standards to assure public water safety in supply systems, including CEN/TC 164 – water supply, CEN/TC 165 – wastewater engineering, ISO/TC 224 - service activities relating to drinking water supply systems and wastewater systems - Quality criteria of the service and performance indicators and ISO/TC 282 – water reuse. Additionally, there are norms and standards developed at a national or European level, targeted to taps and fittings, which are important to address under this topic.

Water-using products are also targeted by regulation. Equipment such as dishwashers or washing machines have dedicated European legislation through the eco-label and the Eco-design directive. The strategy behind this type of methods is to raise consumer awareness and promote the continuous water efficiency improvement in these products.

Water labelling schemes are useful to make the characterisation of the water points (indoor and outdoor fixtures/equipment), provided there is a label with the identification of the water and energy usages. In the case of water fixtures, observations may include the existing technology, flow and energy use, at the tested conditions. In the case of equipment (water and energy production appliances), the amount of water and energy may be shown per cycle or yearly usage. Relatively to the existing water labelling schemes, they can refer to different types of fixtures or equipment, use different ranking references or be more/less general.

Examples of those labelling schemes include: ANQIP, WELL, Water Wise, Water Sense, WELS and the Unified Water Label. The unified water label is a voluntary scheme created to allow the consumers to have information regarding taps and showers in terms of energy and water efficiency. Figure 2.4 shows the water consumption target (5 litres/min) and the respective energy consumption (100 kWh / (person.year)), ranked by colour, from the lowest efficiency (in red) to the highest efficiency (in green). The unified water label is a concerted action combining different labelling schemes and seeks to be the only label taking place in Europe from 2021 on.

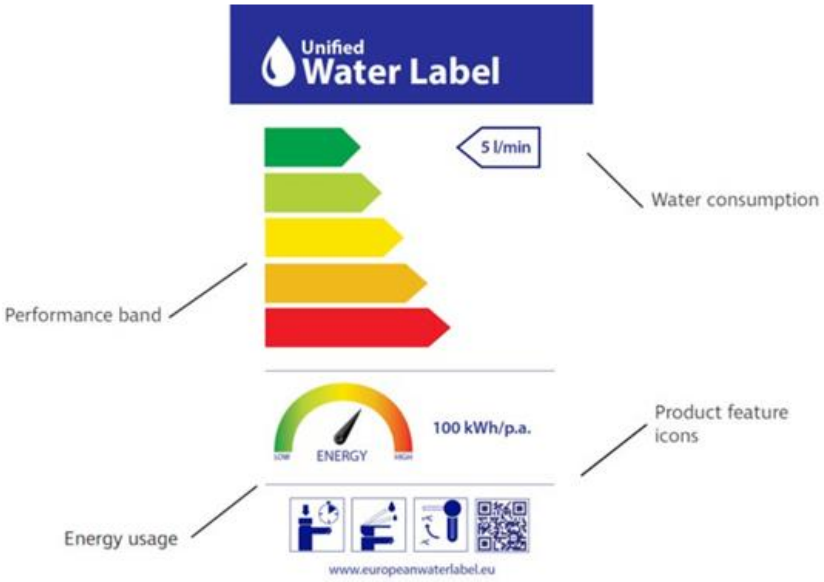

Figure 2.4: Unified water label model

[Source: http://www.europeanwaterlabel.eu/thelabel.asp]

Apart from labelling schemes, there are also performance and sustainability evaluation systems, with broader scope than the ones used for product labelling, such as BREEAM, LIDERA, LEED or GBI. It is also possible to find isolated measures defined by the regional governments such as in some Italian provinces where new buildings must have dual-flush toilets with maximum and minimum flush volume or in Spain where all bathroom taps must ensure water savings.

Overall, water efficiency regarding water-use equipment in building is driven mostly by good practices and consumer awareness and not by regulation. With the increasing need for water efficiency due to freshwater scarceness the European Union and other countries have water efficiency on their agendas and some of the good practices identified may become mandatory.

Unit 3: Identification and prioritization of water-energy saving measures

Introduction / General description

Monitoring can be a short or long process in buildings, depending on many factors, including the objectives, the level of detail assessed and the associated budget. Likewise, special equipment and the meters that may be selected may differ whether discrete or continuous monitoring is in place.

Unit 3 provides the methods used for the identification and prioritization of water-energy saving measures in order to improve knowledge for defining the procedures for the assessment of field data derived from water-energy balances necessary in buildings, and to identify good practices in water-energy monitoring/auditing. Examples of application of 'alternative' water-energy saving measures are further provided.

Scope – Expected results

At the end of this Unit, the candidate should be able to:

- assess field data derived from water-energy balances for buildings;
- recognise the basic characteristics and savings derived from the application of 'alternative' water-energy saving measures;
- prioritize water-energy saving measures;

This Unit is constituted by 2 lessons:

LO1: Alternative water-energy saving measures identification and prioritization

LO2: Good practices in water-energy efficient usage

Key words / basic terminology

Prioritization and implementation of efficiency measures, good practices towards water and energy efficient usage.

3.1 Alternative water-energy saving measures identification and prioritization

In the process of a water-energy monitoring plan or audit, identifying the monitoring priorities is required to reduce time and costs. In large buildings, representative sampling may replace monitoring of all points, owing that the most relevant are selected, together with good allocation of resources and metering devices.

Depending on the building type, the expert technician or auditor can identify spaces that are responsible for most of the water and energy consumption, meaning the hotspots. For example, in large buildings most of the water consumption may be associated with restrooms and kitchens, and other spaces might be relevant such as: green spaces, heating and cooling units and relevant laboratorial or industrial processes.

Monitoring spaces instead of individual systems may also fall into IPMVP M&V Option C, so that the overall performance of the building is assessed through continuous measurements. It is the expert technician and auditor responsibility to decide the approach and measurements that need to be undertaken in a monitoring plan that should be discussed with the owner/consumer of the building/household.

Like in space prioritization, system prioritizing can be used to reduce metering resources. Building spaces usually include several systems so measuring systems instead of spaces may lead to the need of more metering resources but also provides an increased accuracy. System metering falls into IPMVP M&V Options A and B, meaning partial or full measurements and short-term to continuous reporting, that according to IPMVP should be used for isolated efficiency measures implemented in a building.

The key systems in water and energy consumption are:

- Water supply network
- Washing machines
- Faucets
- Irrigation
- Heating, Ventilation and Air Conditioning (HVAC)
- Lighting
- Others.

3.2 Good practices in water-energy efficient usage

Identifying energy and water efficiency measures is one of the goals of the monitoring and auditing. The technical expert or auditor performing should combine experience with monitoring results to be able to identify efficiency measures, especially those with reasonable payback periods and investment values as building owners often have limited budget to implement the efficiency measures. The pressure to reduce building operation costs is one of the motivations for building owners to request audits.

3.2.1 Daily profile

Daily profiles of energy and water consumption are great tools to find consumer behaviour pattern and identify the potential measures. This may be a response to patterns that are associated with activities or specific systems inside the building that can reveal inefficient behaviours or malfunctioning equipment. When assessing the water consumption profile, the assessment of water losses is of upmost importance.

The common analysis of daily profiles usually includes the identification of the base and peak consumption, as well as sudden drops or rises in consumption. Other valuable information might be extracted by comparing the daily profile with other data collected in the audit. Although daily profiles can be very different for building to building or for energy and water consumption, a similar analysis can be used, focusing on base, peak, rises and drops in consumption.

Figures 3.1 and 3.2 show examples of daily profiles of water consumption in a residential household and energy consumption in a service building. In Figure 3.1, there is minimum consumption during the night and two peaks around lunch (11-12 h) and dinner (19-20 h) time or meal preparation. The minimum flow during the night could be related with low consumption or, if continuous, night losses in the supply network.

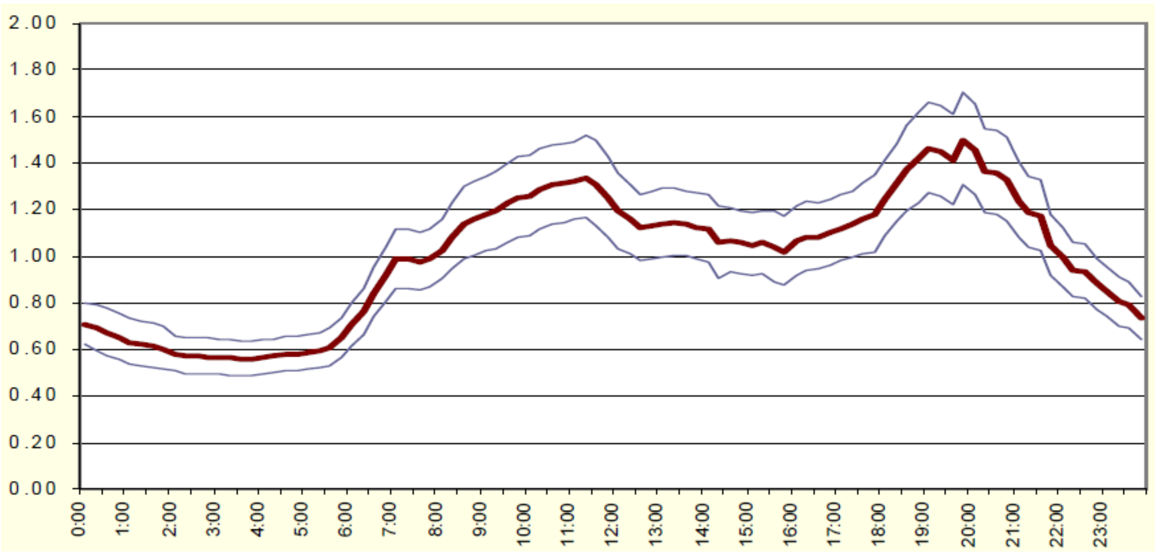

Figure 3.1: Daily non-dimensional profile: consumption/average daily flow per time (hh:mm)

[Source: ERSAR, Technical Guide nº8 (in Portuguese)]

Analysing the pattern in Figure 3.2, it is possible to identify that the consumption starts to increase at 5:00 and decreases at 18:00, indicating the period when the building is being used. This may be further supported by evidence, e.g., showing that most of the people arrive at 9:00. Also, the cleaning service may be responsible for the energy consumption between 5:00 and 9:00, if the lighting system is on in most of the building.

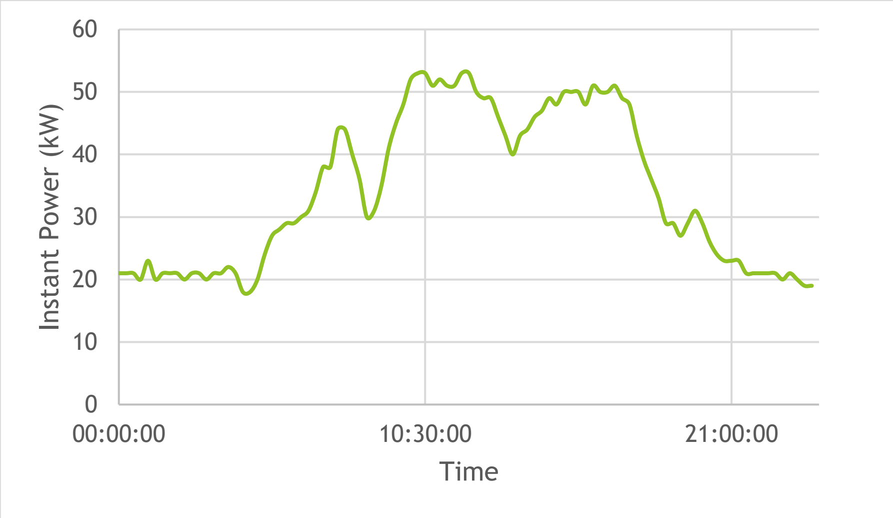

Figure 3.2: Daily (workdays) profile: instant power (kW), from educational building

3.2.2 Consumption per space and per system

Breakdown of consumption per space is usually performed to find the spaces that should be targeted by the efficiency measures, allowing the payback period for the efficiency measures to improve significantly. To separate consumption by spaces is usually needed to use sub-meters that enable the individualization of these spaces. In some cases, the expert technician or auditor can use data collected in a space to try to isolate it without resorting to sub-metering as this brings additional costs for the audits.

At the residential building sector, the most representative uses (Figure) are usually associated with showering and bathing, with ca. 39%, leaving equipment/appliances (dishwasher and washing machines) with ca. 20%. Changes in the consumption distribution profile may be due to variations in outdoor areas, which are also affected by the geographical location of the building, climate and season of the year. Water losses (not shown in the figure) are usually around 4-5% and may be attributed to leakage in the distribution network, fixtures and appliances.

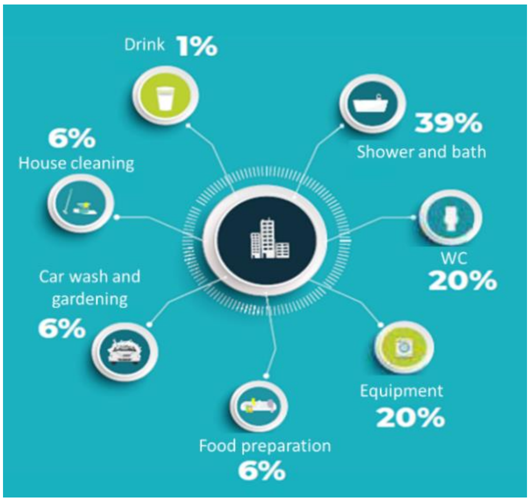

Figure 3.3: Overall water consumption distribution per uses in a residential building (adapted from Aqua Experience e-book, 2018)

In Figure it is possible to see a breakdown of energy consumption for an educational building. The breakdown separates the school in four areas: the reception, the gymnasium, the kitchen and the school itself (classrooms). In this breakdown the school area (classrooms) are the main responsible for the energy consumption of the building, with approximately 50% consumption. Other approach is to characterize the spaces in terms of energy intensive consumption: if the gymnasium corresponds to approximately 40% of the energy consumption despite having lower (< 40%) representation in total floor area.

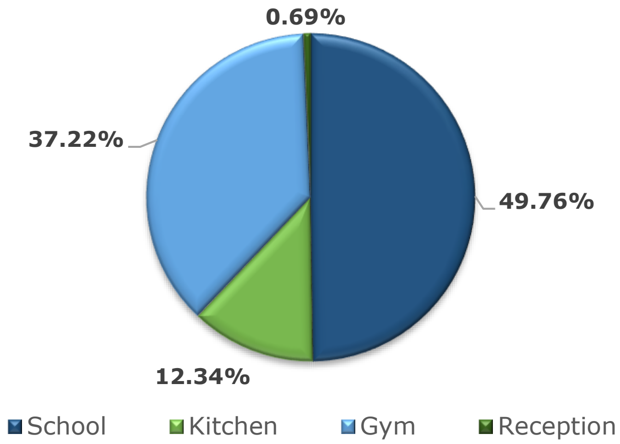

Figure 3.4: Example of a space breakdown of energy consumption that may ideally occur in an educational building

Performing a breakdown per system provides complementary data to space breakdown, while monitoring of individual systems may imply the use of sub-meters, thus the adding of complexity and costs. In Figure , the breakdown, deployed by the installation of sub-meters, highlights lighting and heating systems, as well as the kitchen equipment. Similar breakdowns can be performed for water consumption.

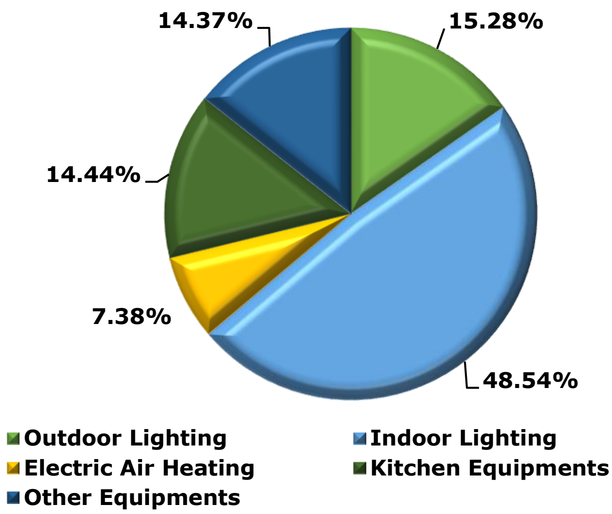

Figure 3.5: Example of a system breakdown of energy consumption that may ideally occur in an educational building

Unit 4: Monitoring cost-benefits and impacts from applying water-energy saving measures

Introduction / General description

Regular variance in water and energy consumption is an apparent problem for estimating real savings obtained with efficiency projects. To work around this problem, Unit 3 focus on the development of baselines, the basis for estimating future water and energy consumption. Here, in Unit 4, the focus is to use that baseline to assess the real water and energy savings obtained with the project, by comparing the baseline prediction curve with the monitoring consumption. Unit 4 also covers the cost-benefit analysis and impacts of water-energy saving measures as well as suggesting and identify good practices in water-energy efficient usage.

Scope – Expected results

At the end of this Unit, the candidate should be able to figure out:

- cost-benefits of alternative water-energy saving measures;
- other impacts of alternative water-energy saving measures;
- ways to monitor alternative water-energy saving measures performances;
- ways to verify the positive effect of alternative water-energy saving measures.

This Unit is constituted by 2 lessons:

LO1: Cost benefits from and other impacts of water-energy saving measures

LO2: Monitoring and verification of the impacts of water-energy saving measures

Key words / basic terminology

Implementation of efficiency measures, regular functioning of the system, verification and communication criteria.

4.1 Cost benefits from and other impacts of water-energy saving measures

The process of calculating the savings obtained with the implementation of efficiency measures is directly related with the development of the baseline. The baseline allows to predict future energy consumption and this prediction can be compared with the real data to achieve the result savings of the efficiency measures.

Figure 4.1 schematizes the definition of using the baseline to calculate savings. Therein, after project implementation and considering the measurement baseline, the predicted consumption may be estimated. This may be further supported with real data to allow the verification of the water and energy savings.

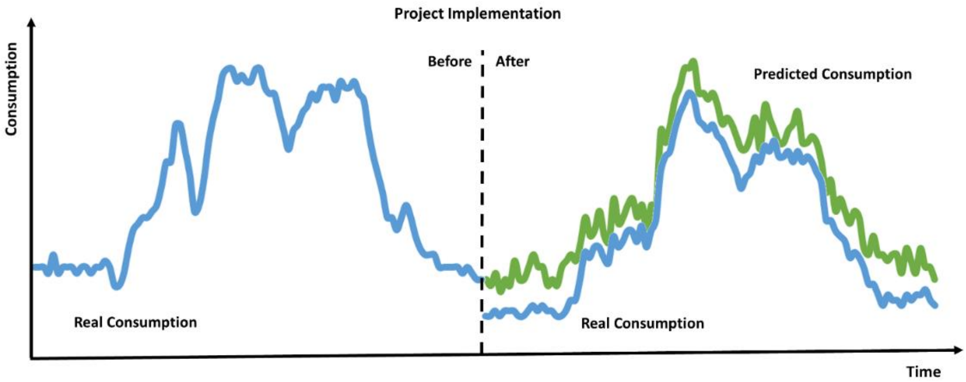

Figure 4.1: Example of an overall water consumption distribution that may ideally occur in an educational building

The typical water-energy efficiency measures that can be comprehensively analysed by the expert technician and auditor may be separated as follows:

- Large intervention water-energy efficiency measures – those that take from weeks to months (per measure) to be implemented. These may need the residents to leave the building/household during intervention.
- Short intervention water-energy efficiency measures - those that take from days to a week (per measure) to be implemented. These may need the residents to leave the building/household during intervention.

Large intervention measures include design, new installation and complete rehabilitation, and short intervention measures those referring to adaptation or partial rehabilitation, installation, replacement or improvement of equipment, fixtures, etc. All these measures should be carefully analysed through a cost-benefit study considering the technical performance, financial, environmental and quality strategies / approaches.

4.2 Monitoring and verification of the impacts of water-energy saving measures

The process of undergoing the building/household monitoring for water and energy efficiency is useful to assess the global performance of the system. Key performance indicators, the identification of target upon the implementation of efficiency measures, the assessment of the possible impacts of the measures and a short- to long-term analysis on how the system will behave are important outputs that may be drawn throughout a monitoring and audit plan implementation.

Key performance indicators will provide an overview of the system, enabling decision-making processes and the identification of efficiency actions plans. Providing simple indicators that all building stakeholders can understand raises awareness for water and energy consumption and facilitates the acceptance of implementation of efficiency measures.

The following steps to be supported by key performance indicators may be achieved when performing a monitoring/auditing plan:

- Identify water and energy efficiency drivers in the building
- Understand the behaviour profile
- Recognize cause-effect relationships
- Prepare actions plans for efficiency improvements
- Communicate *status quo*.

REFERENCES AND FURTHER READINGS (MEDIA & RESOURCES)

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SELF-ASSESSMENT QUESTIONS FOR MODULE 3

1.	**When monitoring water networks, which of the parameter is not considered a priority for monitorization:**	
	a. Temperature	√
	b. Humidity	
	c. Pressure	
	d. Flow Rate	
2.	**A flowmeter that can use the rotation of a turbine to assess the flow rate is typically categorized as a:**	
	a. Positive Displacement Meter	
	b. Differential Pressure Meter	√
	c. Velocity Meter	
	d. Ultrasonic Meter	
3.	**Ultrasonic flowmeters are widely used in audits because of:**	
	a) their portability and for being non-intrusive.	√
	b) their portability and their high accuracy.	
	c) their communication capacity and low need of recalibration.	
	d) their communication capacity and low cost.	
4.	**What is the international system unit for energy?**	
	a. Watt-hour	
	b. Kilowatt-hour	
	c. Joule	√
	d. Calorie	
5.	**In a water-energy audit, the purpose of the ex-ante analysis is to:**	
	a. Meet the client and handle all bureaucracy before the start of the monitoring / auditing process	
	b. Process all the data collect so it is possible to develop a pre-monitoring or audit report	
	c. Gather information about the building and process it to plan the monitoring / audit	√
6.	**Which of the following options is true regarding IPMVP?**	
	a. IPMVP is only applicable for large projects	
	b. IPMVP has a unique approach regarding residential and tertiary buildings	
	c. IPMVP does not consider an option based on simulation	
	d. IPMVP considers M&V options for targeted measures	√
7.	**Consumption baselines are:**	
	a. A forecasting technique used in data analytics to eliminate variance in water and energy consumption.	
	b. A mathematical method of comparing current consumption with consumption prior efficiency project.	√

	c. A method to automatically find water and energy efficiency measures adapted to the case study building.	
8.	**During a pre-audit in a building with two spaces (space A and space B) it is identified that system A is responsible for 80% of water consumption. What is the most correct way for the auditor to proceed with metering?**	
	a. Monitor both spaces with similar detail and number of meters	
	b. Monitor only space A but using a large number of meters to ensure a correct characterization	
	c. Monitor space A with more detail and with a larger number of meters but also monitor space B	√
9.	**During the analysis of collected data, the auditor builds a water consumption daily profile and notices that the base consumption is 1 cubic meter per hour. The auditor is informed that all water consuming equipment is off during the night. This could be an evidence of (choose all correct options):**	
	a. Uncalibrated water meter.	√
	b. Leakages.	√
	c. Wrong M&V methodologies.	
	d. Occupant bad practices.	
10.	**Key performance indicators provide:**	
	a. A comprehensive way for treating the data collected during the audit.	
	b. An overview of the system and enable decision-making processes.	√
	c. A method of communication between suppliers and service companies to facilitate commissioning.	

MODULE 4: COMMUNICATION WITH CUSTOMERS

SUMMARY

Water uses in buildings may be those for cooking, house cleaning, cloth and dish washing, personal hygiene (toilet flushing, bathing and showering) or outdoor, including terraces, vehicle washing and swimming pools. Daily use of household water is, on average, 144 litres per capita (per person per day), even if it may be considered 20 to 50 litres per capita as the minimum to meet basic daily needs. Demand is, however, dependent of multiple factors, including age, health conditions, income level, household size, water utility or geographical area.

The efficiency of water use may be achieved through reduction of water losses, higher water efficiency in devices/products, new technologies or network configurations, as guaranteeing the quality, safety and comfort in use. The use of alternative sources, with different uses and quality needs ("fit-for-use" purposes) includes: rainwater harvesting and wastewater reuse. Consumer behaviour and water leakage are important factors affecting water demand, with urban areas having higher demand than rural areas.

Communication with customers/ consumers is essential to guarantee that water and energy supply and usage are adequately maintained and used efficiently, with minimal water and energy inefficiency. Good counselling on the adequate infrastructure, together with the correct selection of fixtures and appliance, can help them limit their water and energy demand, with positive saving effects on household water and energy bills. The use of standards of water efficiency and energy efficiency in buildings, together with new solutions and technologies, may be important drivers to the promotion of water efficiency.

Herein, and aligned with a possible route of the expert technician and auditor patch into the building / household (from outside to the inside), water systems may be divided into the following fundamental component groups: water sources and infrastructure, outdoor uses, water fixtures, water appliances and domestic hot water production.

This is the 4th of four Water Efficiency Expert (WEE) Modules that the WATTer Skills project has produced. This Module integrates the three following Units:

Unit 1: Auditing, diagnosis and definition of consumption baseline, benchmarking and identification of water-energy saving potentials

Unit 2: Identification of water-energy efficiency measures and equipment to attain water-energy saving potentials and formulation of a documented proposal to the customer

Unit 3: Promotion of best practices for the correct use and maintenance of water-energy efficiency systems.

The 1st Unit of Module 4 deals with the principles of auditing, diagnosis and definition of consumption baselines, useful for benchmarking and identification of water-energy saving potentials. This includes a preliminary study for data gathering and definition of the overall audit approach, including the necessary tools (i.e., measuring equipment, material) to onsite measuring and the necessary documentation to prepare the field visit information report.

The 2nd Unit of Module 4 deals with the principles of advising on the implementation of water saving measures, including recognising the potential savings with basis on a diagnosis, identification of improving efficiency measures to increase building performance and the elaboration of a proposal to the customer/consumer.

The 3rd Unit of the Module 4 deals with the identification of best practices to guarantee the regular well-functioning of the equipment or the installation. This includes the identification of criteria and methodologies for the verification, inspection procedures and strategies to make the identification of the water and energy baselines and attest the overall system performance.

Unit 1: Auditing, diagnosis and definition of consumption baseline, benchmarking and identification of water-energy saving potentials

General description

Undergoing an audit to a household regarding water and energy related efficiencies may be useful in the stage of project or with building/household under use. Water uses in buildings include cooking, house cleaning, cloth and dish washing, personal hygiene (toilet flushing, bathing and showering) or outdoor, including terraces, vehicle washing and swimming pools. Household water systems may be comprised of the following fundamental component groups: water sources and infrastructure, outdoor uses, water fixtures, water appliances and domestic hot water production.

The basis for the definition of a dedicated audit approach is presented, including the key steps for planning an audit or visit to a household, conduction of a diagnosis and identification of the consumption baseline for assessing household water system performance. Identification of the water consumption baseline allows the auditor to give advice and guidance to the customer/consumer, including possible behavioural and infrastructure efficiency measures, to the improving of the overall building/household performance and resilience.

Scope – Expected results

At the end of this Unit, the candidate should be able to:

- identify the main steps towards the execution of an audit plan or diagnosis to buildings / households;
- select instrumentation for measuring and monitoring water and energy demand;
- implement an audit plan.

This Unit is constituted by 3 lessons:

LO1: Planning a water-energy audit to the building/household

LO2: Identifying the instruments/tools to conduct a water-energy nexus audit

LO3: Collecting, registering and interpreting the obtained results.

Key words / basic terminology

Water network, consumer behaviour, water fixtures, water demand, inspection and auditing.

1.1 Planning a water-energy audit to the building/household

The process of performing an audit and undertake a diagnosis for consumer profile assessment, benchmarking and identification of the saving potential is sustained through onsite measurements and observations. This combines a preliminary study, an audit/diagnosis of the household/building and sampling and monitorization.

To make an estimation and assessment of the building water balance, including the energy use under the water-energy nexus, some basic elements need to be provided by the customer/consumer to the technician expert or auditor. More precisely, the auditing procedures are as follows:

- **Preliminary study**: The preliminary study is conducted before the first visit to the building / household. The owner/user should provide the existing and available documentation regarding the building, including information over the infrastructure, including supply and distribution network systems, fixtures, appliances or additional elements of technical, financing or administrative nature, considered useful to building characterisation. This information is helpful to do the visit plan, including an estimation of the time needed to perform the visit, the necessary equipment and the building geography. The collected data and resulting information should be used to produce a preliminary characterisation report.

- **Building/household profile diagnosis**: After the identification of the building/household profile, the technician expert or auditor may undertake the inspection or audit. This includes an evaluation of the building/household baseline, including the standards and benchmarking analysis of the existing fixtures, appliances and water alternatives sources (e.g., rainwater harvesting or greywater reuse). This information is important to estimate consumer demand profile and prescribe water efficiency measures. Regarding the water utility supplier, data on the quality of the service provided (e.g., water tariffs, pressure levels) and the infrastructure (e.g., leakage), may be useful for the definition of water saving measures and analyse measure implementation paybacks.

1.1.1 Preliminary study

The preliminary study (before the first field visit) should include a survey to the owner/user and a request to have access to the available documentation regarding the building, infrastructure, system, appliance, fixtures or any elements on the technical, financing or administrative aspects, useful for building characterisation. With respect to the possible available documentation, the following may be considered as necessary:

- Basic elements in building/household at the design, construction or built stages: water and wastewater networks (written elements, measurements and drawings), outside area with irrigation network (written elements, drawings), architecture or final drawings (if concluded), pool characteristics (type of treatment, covering, equipment and water saving strategies);
- The manual of the building/household, the maintenance plan and the logbook of the main building/household interventions (renovation or replacement of pipe, fixture or appliance), provided by the constructor or the owner;
- Technical specifications or catalogues of the fixtures (brand, model, functionality, flow), appliances (brand, model, functionality, water and energy usage) and domestic hot water

production systems (model and energy source), e.g., provided by the respective suppliers at the time of buy or rehabilitation;
- Acquisition bills or any other documents of administrative relevance that may refer to the installed equipment, fixtures, materials, etc.;
- Service (water and energy) bills, preferably from the last 2-5 years and after the latest infrastructure intervention (replacement of pipe, fixture or equipment);
- Technical and scientific references (e.g., labelling) from national or independent authorities with non-commercial claim for performance evaluation of the installed components.

Based on the provided information and documentation, which may vary with the owner/user or the regulatory mandatory procedures, different information can be provided. The collected data and resulting information should be used to produce a preliminary characterisation report, where the type of building/household in-hand (e.g., apartment, house) and construction stage at the time of the audit/visit (e.g. project, new building, old building) need to be identified.

1.1.2 Building/household profile diagnosis

- **Consumption profile**

Household water systems may be comprised of the following fundamental component groups: water sources and infrastructure, outdoor uses, water fixtures, water appliances and domestic hot water production. With basis on these typical consumptions taking place in residential buildings, the overall audit approach will consider five main areas:

1. Water sources and infrastructure – alternative sources of water and the water network distribution infrastructure;
2. Outdoor uses – exterior area property of the building/household owner/user, including garden, pool, garage, roof;
3. Water fixtures – taps, toilets, shower heads or other types of fixtures present;
4. Water appliances – washing machines and dishwashers;
5. Domestic hot water production – energy production equipment and domestic hot water network.

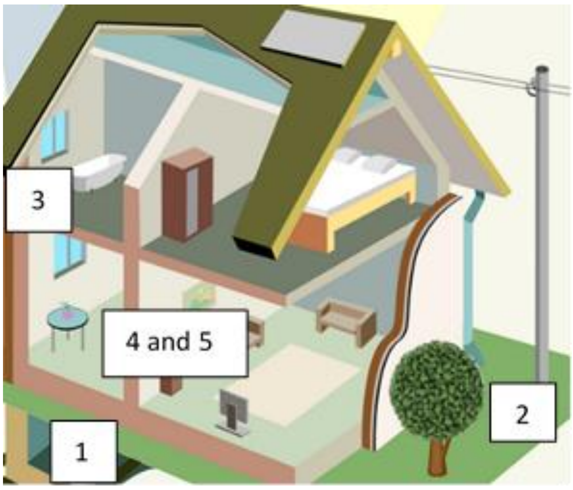

Figure 1.1: Five main water consumption areas in buildings: (1) water sources and infrastructure, (2) outdoor uses, (3) water fixtures, (4) water appliances, (5) domestic hot water production

[Source: AQUA+ project, promoted by ADENE]

Consumption profile may be assessed through a survey, where the owner/consumer provides information regarding the overall use of the building/household (e.g., in use, no use) and occupation (e.g., main/temporary, number of people). The survey should also include questions regarding consumer habits/behaviour, to further assess water fixture and appliance water and energy usages, as well as calculation of the potential savings derived by the implementation of water saving measures.

At the residential building sector, the most representative uses (Figure 1.2) are usually associated with showering and bathing, with ca. 39%, leaving equipment/appliances (dishwasher and washing machines) with ca. 20%. Changes in the consumption distribution profile may be due to variations in outdoor areas, which are also affected by the geographical location of the building, climate and season of the year. Water losses (not shown in the figure) are usually around 4-5% and may be attributed to leakage in the distribution network, fixtures and appliances.

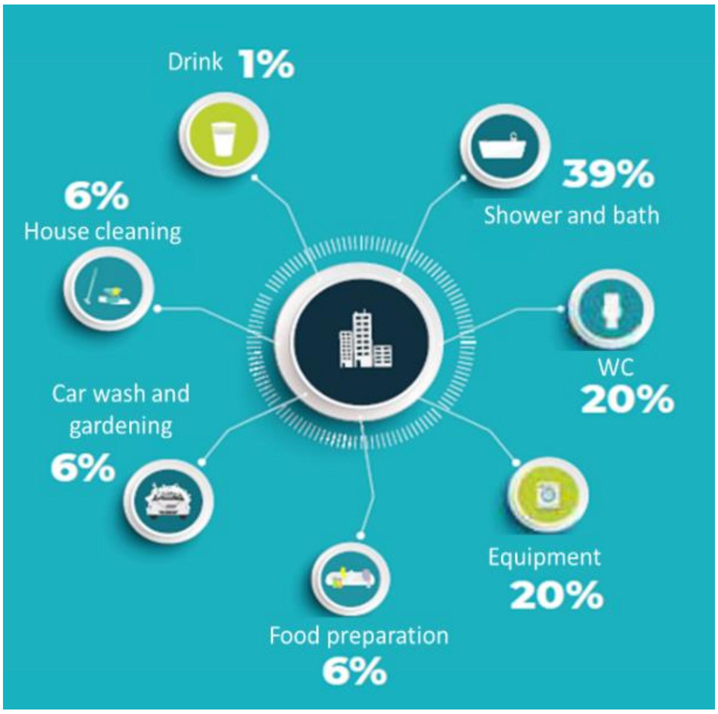

Figure 1.2: Most representative uses of water at the residential sector (adapted from Aqua Experience e-book, 2018)

The frequency of use and the time per use are important variables for calculations and may vary within different households. In the lack of data, assumptions can be made for overall estimation of household uses, since for people with similar behaviour often show similarities in the daily water demand patterns (Figure 1.3). Typical assumptions may include assuming daily basis water usage, i.e., without any differences between workdays, weekends and holidays, or e.g., a flat consumption rate between age and gender.

The water consumption pattern from Figure 1.3 shows the variation of the water consumption in a typical household, with an early peak and a late peak, possibly corresponding to people bathing and cooking, a phenomenon often called “duck effect”.

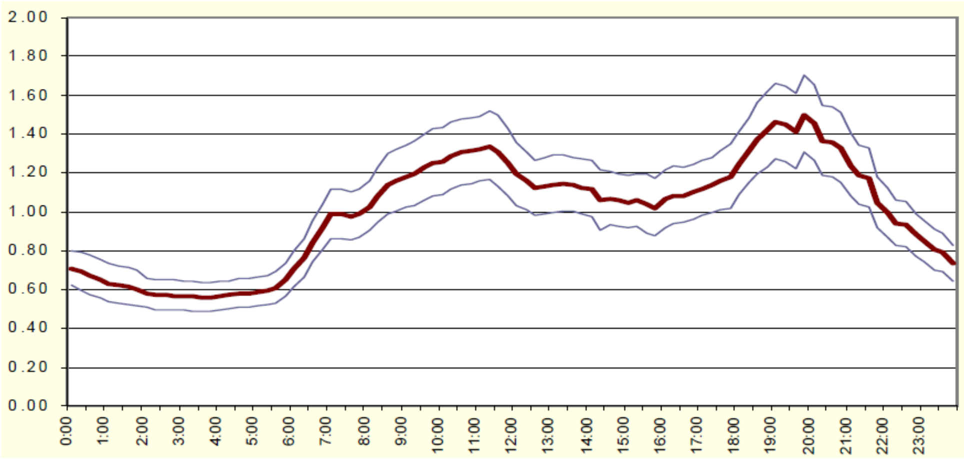

Figure 1.3: Daily non-dimensional profile: consumption/average daily flow per time (hh:mm)

[Source: ERSAR, Technical Guide nº8 (in Portuguese)]

Differences in the water consumption pattern may be expected, as shown by Figure , e.g., due to differences in observed demand patterns, given different life qualities or geographical areas. The study was conducted in Portugal, but the obtained daily consumption patterns may be observed elsewhere. Based on the study, consumption may be characterised considering six periods: transition (06-07h and 22-01 h), morning (07-10 h), lunch (10-15 h), and dinner (19-22 h). Considering different daily average routines, different time schedules may need to be considered.

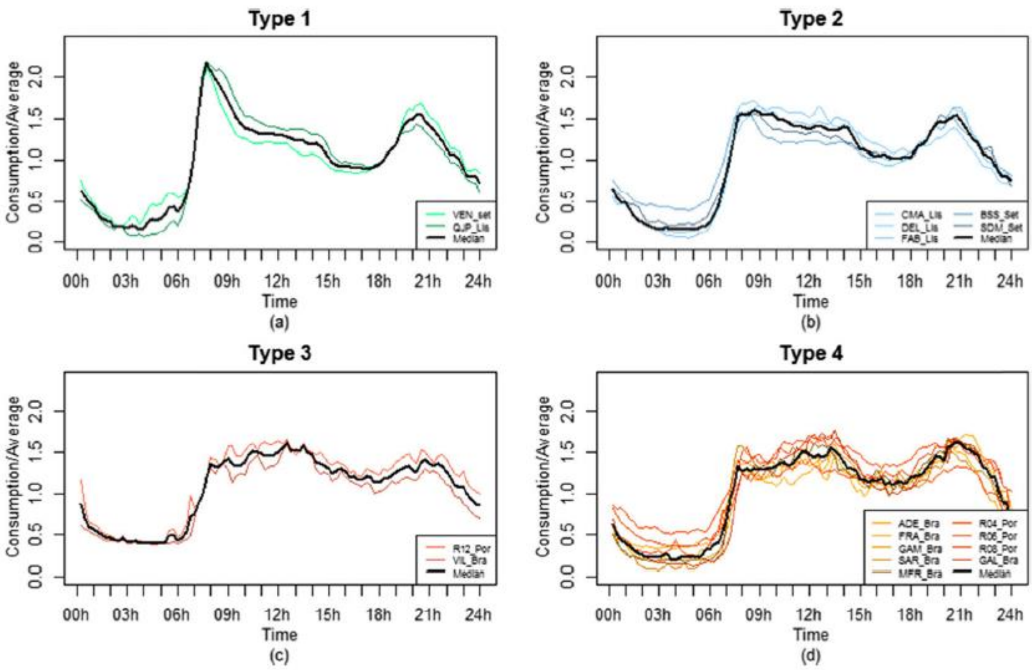

Figure 1.4: Variation in daily consumption patterns respective to different pattern types: 1) maximum value in the morning, 2) largest consumption during the day, 3) higher demand in the morning and lunch periods and 4) largest consumption at lunch and dinner

[Source: Loureiro et al., 2016]

The "duck effect" may be observed when water and energy usages are translocated (Figure 1.). Due to costs and environmental impact, it may be useful, whenever possible, to carry out system adaptations towards improved syncing between demand and resource availability. In the case of energy, this may consist in decoupling energy production and usage, through the storage of energy during solar periods (e.g., through photovoltaic equipment) and its use in demand peaks, reducing the need of peak power energy plants and the high costs associated.

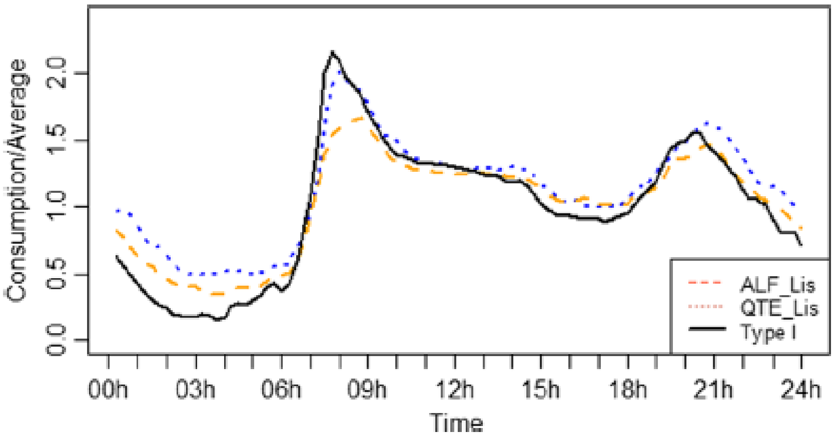

Figure 1.5: Observation of the "duck effect"

[Source: Loureiro et al., 2016]

- **Water labelling**

Water labelling schemes are useful to make the characterisation of the water points (indoor and outdoor fixtures/equipment), provided there is a label with the identification of the water and energy usages. In the case of water fixtures, observations may include the existing technology, flow and energy use, at the tested conditions. In the case of equipment (water and energy production appliances), the amount of water and energy may be shown per cycle or yearly usage. Relatively to the existing water labelling schemes, they can refer to different types of fixtures or equipment, use different ranking references or be more/less general.

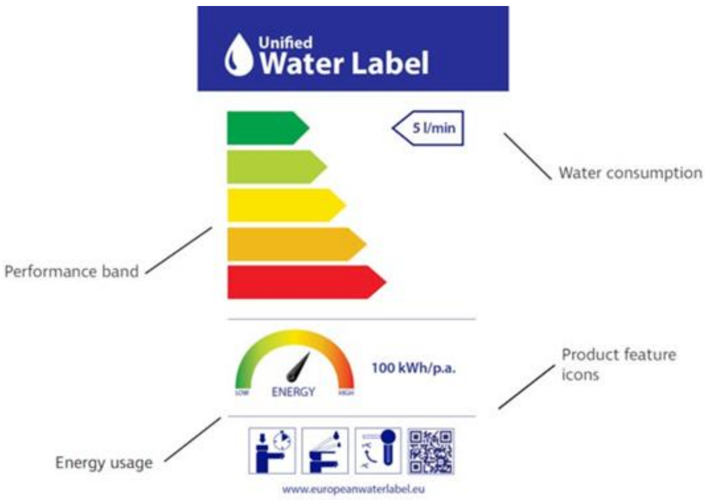

Figure 1.6: Unified water label model

[Source: http://www.europeanwaterlabel.eu/thelabel.asp]

Examples of those labelling schemes include: ANQIP, WELL, Water Wise, Water Sense, WELS and the Unified Water Label. The unified water label is a voluntary scheme created to allow the consumers to have information regarding taps and showers in terms of energy and water efficiency. Figure 1.6 shows the water consumption target (5 litres/min) and the respective energy consumption (100 kWh / (person.year)), ranked by colour, from the lowest efficiency (in red) to the highest efficiency (in green).

The unified water label is a concerted action combining different labelling schemes and seeks to be the only label taking place in Europe from 2021 on. Apart from labelling schemes, there are also performance and sustainability evaluation systems, with broader scope than the ones used for product labelling, such as BREEAM, LIDERA, LEED or GBI.

1.2 Identifying the instruments/tools to carry out water-energy auditing

A diagnosis of the building infrastructure should consider the definition of the sampling approach, including the identification of the necessary instrumentation and implementation to the diagnosis of each water point. This information is important to estimate consumer demand profiling or to the evaluation of the impacts of the implemented water efficiency measures.

1.2.1 Definition of the sampling approach

Definition of the sampling approach (Figure 2.1, with an example provided in Figure) includes definition of:

- the sampling method (discrete or continuous),
- the measuring type (qualitative or quantitative),
- the data acquisition period,
- the monitoring timeframe, and
- equipment installation (invasive or not-invasive).

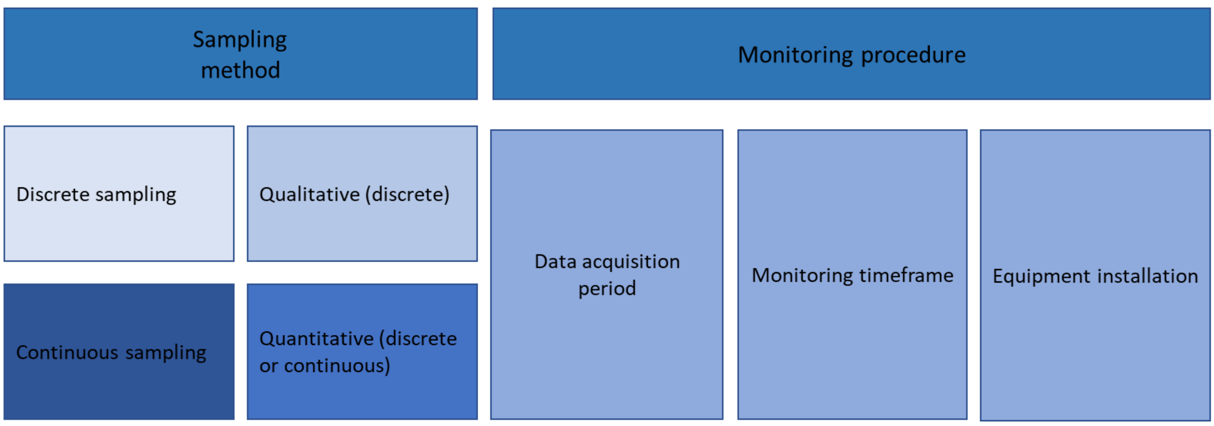

Figure 1.7: Sampling approach: sampling method and monitoring procedure

The number of fixtures/equipment to analyse should include total number of taps (kitchen, sink and bide), the total number of toilet flush and any other water points, as part of the building/household. The technology for each of the fixture/equipment observed needs to allow guidance over the possible technologies promoting water saving behaviour (e.g., dual flushing systems). The age of the fixtures/equipment may allow to suggest maintenance measures or the pertinence of improved rehabilitation. The definition of the sampling approach should be done by the time of the preliminary study.

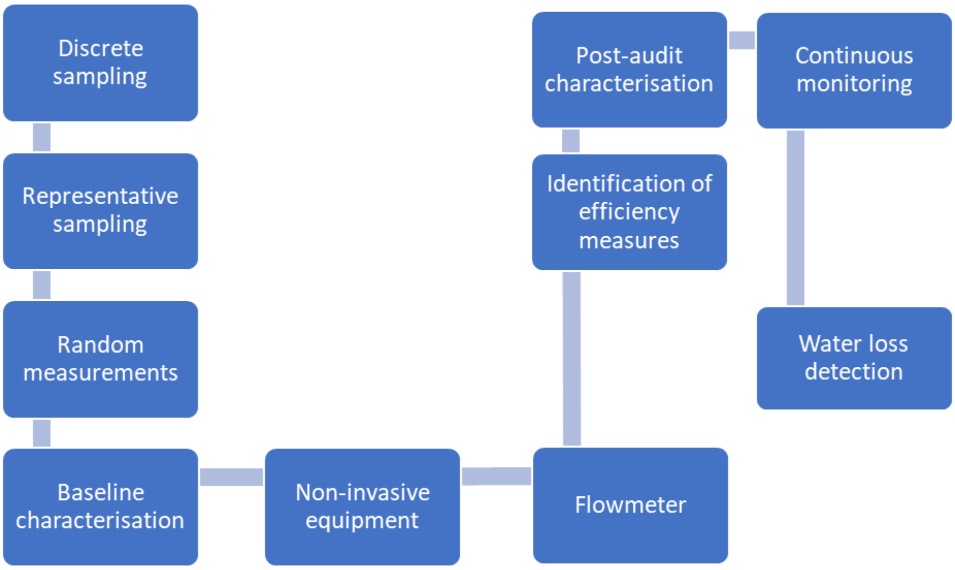

Figure 1.8: Example of a sampling approach

1.2.2 Sampling and monitoring

In a building/household, the set of measuring equipment that may be included to assess water efficiency performance evaluation may be as follows:

- Flowmeter – adequate to measure the flow in a fixture or pipe (Figure 1.). Measuring equipment specifications should consider a representative flow length, allowing the possibility of measuring low and high flows in common fixture households. Resolution should be adequate to measure flow in litres per second.
- Calibrated volume – adequate to measure the capacity of a toilet flush. It may be used as a flowmeter together with a time watch. Resolution should be adequate to measure litres.
- Ruler or dimension reader – measuring equipment of dimensions to calculate areas for gardening, garage, etc. Resolution should be adequate to measure cm.
- Thermometer – adequate to measure water temperature. Measuring equipment specifications should consider the need of doing rapid reads and it should not be easily breakable. Resolution should be adequate to measure cold and hot water temperatures of ca. 0-100 ºC.
- Pressure reader – adequate to measure flow pressure in a fixture or pipe. Resolution should be adequate to measure pressure of ca. 1-10 bar.
- Timer – adequate to measure time and assess flow rate together with volume measurements. Resolution should be adequate to measure seconds.
- Thermography – adequate to perform thermal imaging inspection for the detection of temperature differences in distribution pipes (Figure 1.), useful to detect water losses or pipe scaling. Equipment should be adequate to measure distribution water pipes.

Figure 1.9: Flowmeter equipment to measure the flow at fixtures

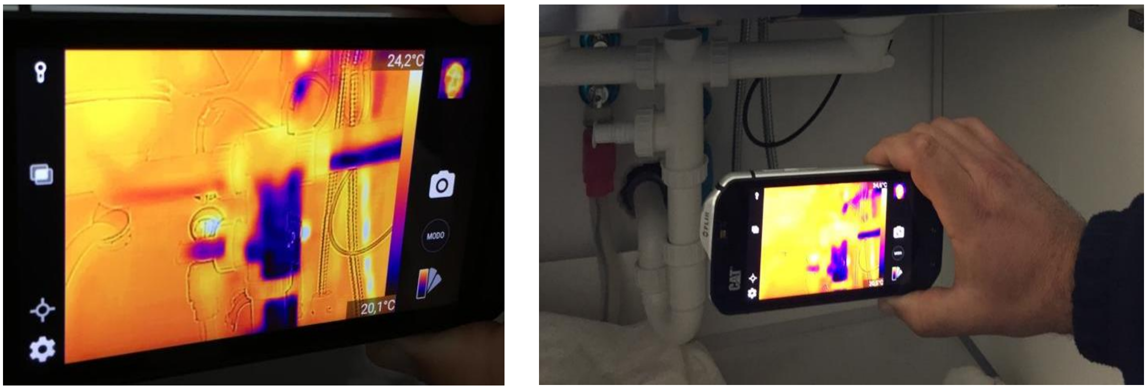

Figure 1.10: Thermographic equipment to measure temperature differences

During the audit, it is important to fill-in an audit sheet and take photographs systematically, as an attempt to make an audit record. The audit should include the number of fixtures and appliances present, existence of flow or volume restrictors, the existence of leakages, or behaviour observations. The diagnosis of the water and energy consumption levels in fixtures and appliances consider all water points. On-field, for installation of the equipment and perform the measurements, specific tools may be required.

With respect to the equipment, the calibrated volume, the ruler, the thermometer and the timer may be used for discrete sampling, while the flowmeter and the pressure reader may be used for sampling and continuous monitoring. Amongst these two, the choice for sampling or continuous monitoring may rely on the required accuracy of the measurements or, for instance, when it is necessary to undergo a comprehensive analysis on the existence of water losses or in finding the consumer behaviour pattern. The appropriateness of using invasive or non-invasive equipment should be carefully evaluated, given differences in accuracy together with the objective of conducting the measurements.

Figure 1.11: Ultrasonic (in-line) water flow equipment (non-invasive)

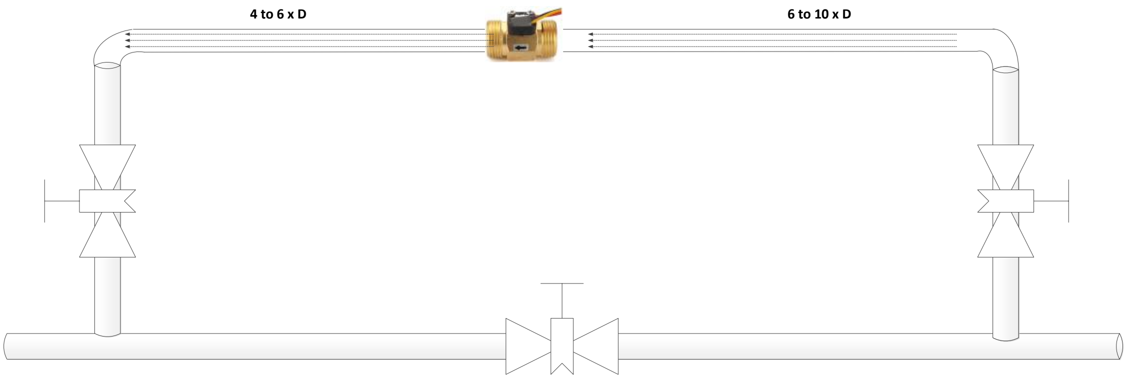

Figure 1.12: Mechanical water flow equipment (invasive)

1.3 Collecting, registering and interpreting the obtained results

The breakdown of the overall estimations over the daily water usage in buildings can be estimated by water use, through fixture/equipment specifications or through measuring, ideally considering equal testing conditions (e.g., pressure and temperature).

1.3.1 Fundamentals

The influencing factors occurring in the different fixtures/equipment are important to be accounted for during the audits and in calculations. Below, some of the influencing factors considered for the characterisation of each device may be referred:

- Flushes - discharge volume, the number of uses per person per day, the number of uses per number of people per household and the technology in place (e.g., dual or single flush);
- Showers – flow, the time of use per person per day, the number of uses per people per household and the technology in place (e.g., water and air mix);
- Taps – flow, the time of use per person per day, the number of uses per people per household and the technology in place (e.g., water and air mix);
- Water appliances (washing machines) – volume per cycle and number of uses per people per household;
- Alternative water sources – availability (rainwater) and possible water reuse destinations (flushes, irrigation).

Besides water demand, for baseline characterisation, the existence of flow restrictors or any other technology inducing consumer behaviour should be identified during auditing, as these may influence consumption patterns and further the definition of water saving measures.

1.3.2 Calculations

Depending on the type of quantity unit in place, the following general equations may be used to the water consumption breakdown in buildings regarding fixtures (toilet flush, shower, toilet tap and kitchen tap) and appliances (dishwasher and washing machines), respectively (Silva Afonso and

Pimentel, 2017). Technology in place, whenever it may provide differences in flow or volume quantity (e.g., dual flush systems compared to single flush systems), should always be observed.

Fixtures daily water demand [litres per day]:

$$W_{fixtures} = \left[\sum(V_{tf} * F_{tf}) + \sum(Q_{sh} * T_{sh} * F_{sh}) + \sum(Q_{tt} * T_{tt} * F_{tt}) + \sum(Q_{kt} * T_{kt} * F_{kt})\right] * N)$$

$W_{fixtures}$ - water demand in fixtures in litres per day
V_{tf} - water volume used per toilet flush in litres
Q_{sh}, Q_{tt}, Q_{kt} - water flow used per shower, toilet tap and kitchen tap in litres/minute
$F_{tf}, F_{sh}, F_{tt}, F_{kt}$ - factors used for toilet flush, shower, toilet tap and kitchen tap respectively
$T_{sh,tt,kt}$ - average time per use in shower, toilet tap and kitchen tap (minutes)
N - Number of household inhabitants

Water appliances daily water demand [litres per day]:

$$W_{appliances} = \frac{(V_{dw} * n_{\emptyset,dw} + V_{cm} * n_{\emptyset,cm})}{365}$$

$W_{appliances}$ - water demand in appliances in litres per day
V_{dw} - water volume used per cycle in the dishwasher in litres
V_{cm} - water volume used per cycle in the washing machine in litres
$n_{\emptyset,dw}, n_{\emptyset,cm}$ - number of cycles in the dishwasher and the washing machine per year

Rainwater harvesting may be evaluated with basis on the availability of rain during the year and the possible uses in the house, namely toilet flush, considering a retention time before use. The reservoir capacity should meet the minimum volume obtained from the following two equations (not standard but proposed by ANQIP specifications), which may be used to the overall estimation breakdown:

Alternative source-rainwater $_{(harvesting\ availability)}$ [litres]:

$$Vr_{1,reservoir} = (0.0015 * Annual\ rainfall_{area} * Collection\ surface * Retention\ period)$$

$Vr_{1reservoir}$ - water volume of the rainwater reservoir in litres
$Annual\ rainfall_{area}$ - rainfall at the specific area of the building per year in mm
$Collection\ surface$ - roof or any other surface to rainwater harvesting
$Retention\ period$ - maximum days for water retention in the reservoir

Alternative source-rainwater $_{(harvesting\ usage)}$ [litres]:

$$Vr_{2,reservoir} = (0.003 * N * Annual\ consumption * Retention\ period)$$

$Vr_{1reservoir}$- water volume of the rainwater reservoir in litres
N - Number of household inhabitants

$Annual\ consumption$ - estimation over the annual consumption (e.g., toilet flush, gardens, etc.)
$Retention\ period$ - maximum days for water retention in the reservoir

With respect to swimming pools and gardens, the approaches are not straightforward, and tailor-analysis may need to be conducted. The following (not standard) equations may be used to perform the overall estimation breakdown regarding daily water consumption in pools and gardens, respectively:

Pool daily water demand [litres per day]:

$$W_{pool} = \left(V_{pool} * \ Pool\ turnover_{year} * 30\ days * pool\ usage\right)/365$$

W_{pool} - water demand in litres per day
V_{pool} - water volume to fill the pool in litres
$Pool\ turnover_{year}$ - renovation rate of the water
$Pool\ usage$ - pool usage in months per year

Irrigation daily water demand [litres per day]:

$$W_{garden} = \left(A_{garden}\ * Cap_{garden} * 30\ days * irrigation\ usage\right)/365$$

W_{garden} - water demand in litres per day
A_{garden} - area of the garden
Cap_{garden} - capitation of the garden in litres per square meter
$Irrigation\ usage$ - irrigation usage in months per year

Considering all the daily consumptions that can be estimated as "water demand" (water net outputs) and, when applied, minus alternative sources such as rainwater harvesting (water net inputs), a water balance/daily water demand for the household can be reached. This considers all the water that is consumed, plus the water total losses (network and fixtures) and non-quantified uses. The total water losses may account for ca. 4-5% of the total water that is consumed. If the water balance is conducted before the implementation of water-energy saving measures, it refers to the "baseline situation" and if it is conducted after the implementation of water-energy saving measures, it refers to the targeted "efficient situation".

Household daily water demand [litres per day]:

$$W_{demand} = W_{base} + W_{total\ losses} + W_{non-quantified}$$

W_{demand} - total water input in litres per day
W_{base} - water consumption in litres per day
$W_{total\ losses}$ - water losses in the network, fixtures and appliances, in litres per day
$W_{non-quantified}$ - non-measured water consumptions in litres per day.

Under an integrated audit approach that considers the water-energy nexus, it is also necessary to estimate the amount of energy that may be saved due to the corresponding water savings. The following equation provides an estimation over the energy that can be saved for domestic hot water (DHW) corresponding to water savings, considering the water that can be saved from a baseline scenario to an efficient scenario, also considering a hot water/cold water relation factor.

<u>DHW daily energy demand [kWh/day]:</u>

$$Q_{Load} = \frac{\Delta W * N * C_P * \Delta T}{3.6 * 10^6} * \left(\frac{F_{DHW}}{\eta}\right)$$

Q_{Load} - Daily energy demand for the total hot water supply of the building in kWh
$\Delta W = (W_{baseline} - W_{efficient})/W_{baseline}$ - water demand in litres per day (baseline)
$W_{efficient}$ - water consumption in litres per day (efficient)
N - Number of household residents
C_P - Specific heating capacity of water (4187 J/(kg·K))
ΔT - Temperature difference between hot water and cold water in Kelvin
$\Delta T = T_{HW} - T_{CW}$ (°C)
T_{HW} - Hot water temperature in °C
T_{CW} - Cold water temperature in °C
η - efficiency of the equipment for energy conversion
F_{DWH} - Daily hot water consumption per daily cold water consumption

Unit 2: Identification of water-energy efficiency measures and equipment to attain water-energy saving potentials and formulation of a documented proposal to the customer

General description

A main advantage of conducting an audit process is to make the identification of water and energy saving measures, to be implemented prior to the construction (project stage) or during the building / household usage, with results in financial and comfort dimensions. Saving measures may be given by each fundamental component group: water sources and infrastructure, outdoor uses, water fixtures, water appliances and domestic hot water production.

Identification of the water and energy efficiency measures allows the auditor to give advice and guidance to the customer/consumer, to the improving of the overall building/household performance and resilience. The expert technician and auditor should be able to present the advantages / disadvantages per efficiency measure, based on the customer/consumer behaviour and expectations, including financial, technical performance and water saving dimensions.

Scope – Expected results

At the end of this Unit, the candidate should be able to:

- make the recognition of the saving potential with basis on a diagnosis;
- identify efficiency measures to improve performance and resiliency of a building/household;
- formulate a documented proposal with the necessary technical specifications to the customer/ consumer.

This Unit is constituted by 2 lessons.

LO1: Identifying water-energy efficiency measures

LO2: Elaborating a documented proposal with technical specifications

Key words / basic terminology

Water efficiency measures, saving potentials, technical specifications, payback period.

2.1 Identifying water-energy efficiency measures

Water-energy efficiency measures may be given by each fundamental component group: water sources and infrastructure, outdoor uses, water fixtures, water appliances and domestic hot water production. These measures will need to account for the behavioural aspects, as these may be useful to estimate the payback period and to undergo sensitivity analysis in the comparison of different types of measures.

There can be different types of efficiency measures, with different priorities, depending on the stage and usage of the building / household. During the project (construction) stage, the infrastructural aspects are more important, as it is easier to undergo large renovation actions at that time. During the usage of the building / household, apart from behaviour, small renovation procedures are easier to be conducted.

The typical water-energy efficiency measures that can be comprehensively analysed by the expert technician and auditor may be separated as follows:

- Large intervention water-energy efficiency measures – those that take from weeks to months (per measure) to be implemented. These may need the residents to leave the building / household during intervention.
- Short intervention water-energy efficiency measures - those that take from days to a week (per measure) to be implemented. These may need the residents to leave the building / household during intervention.

The definition of a proposed measure by the expert technician and auditor should indicate: the component group that it belongs to, a brief description of the type of measure in place, the expected investment, the expected savings and the approximate payback period (Table 2.1). As the type of renovation is variable, also depending on the extension of the measure or the corresponding technical specifications, similarities amongst the measurements in the two types of interventions may be observed. The action of undergoing an audit is an important efficiency measure, although not defined as intervention.

Table 2.1: Water-energy efficiency measures

Type of measure	Component group	Description of the measure	Expected investment	Approximate payback period	Type of intervention
(to fill in)	Water source and infrastructure Outdoor uses Water fixtures Water appliances Domestic hot water production	(to fill in)	(to be calculated)	(to be estimated)	Large intervention (weeks to months) Short intervention (day(s) to a week)

2.1.1 Large intervention water-energy efficiency measures

Identification of the possible measures may be done by component group: water sources and infrastructure, outdoor uses, water fixtures, water appliances and domestic hot water production. Below, examples of the possible water saving measures (considering large interventions) that can be conducted by component group are identified:

- **Water source and infrastructure**
  - Design, installation or rehabilitation of a licensed rainwater harvesting system;
  - Design, installation or rehabilitation of a licensed greywater reuse system;
  - Design, installation or rehabilitation of a licensed outdoor system;
  - Design, installation or rehabilitation of a licensed outdoor supply network;
  - Installation of a smart water metering system for leakage control, with the possibility of remote cut-off and warnings;
  - Design and installation of smart distribution systems, adequate to analyse water consumption / consumer behaviour;
  - Design, installation or rehabilitation of the distribution system (e.g., pipe or valve replacement).

- **Outdoor uses**
  - Design, installation or rehabilitation of adequate irrigation systems (e.g., drip irrigation);
  - Design, installation or rehabilitation of adequate pool distribution systems (e.g., recirculation);
  - Design, installation or rehabilitation of pavements with permeability (to lower runoff peaks);
  - Design, installation or rehabilitation of a green roof (to lower runoff peaks);
  - Design and installation of smart irrigation systems adequate to the existing landscape.

- **Water fixtures**
  - Installation of smart fixture technology to leak detection;
  - Design, installation or rehabilitation of dual supply systems (i.e., potable and recycled water);
  - Design, installation or rehabilitation of heat recovery systems (e.g., bathing).

- **Water appliances**
  - Design, installation or rehabilitation of dual supply systems (i.e., hot and cold water).

- **Domestic hot water production**
  - Design, installation or rehabilitation of efficient hot water delivery systems.

2.1.2 Short intervention water-energy efficiency measures

Identification of the possible measures may be done by component group: water sources and infrastructure, outdoor uses, water fixtures, water appliances and domestic hot water production. Below, examples of the possible water saving measures (considering short interventions) that can be conducted by component group are identified:

- **Water source and infrastructure**
  - Adaptation or partial rehabilitation of a licensed rainwater harvesting system
  - Adaptation or partial rehabilitation of a licensed greywater reuse system
  - Adaptation or partial rehabilitation of a licensed outdoor system
  - Adaptation or partial rehabilitation of a licensed outdoor supply network
  - Adaptation or partial rehabilitation of the distribution system (e.g., pipe or valve replacement)

- **Outdoor uses**
  - Installation of outdoor dedicated flowmeters (e.g., pool flowmeter, irrigation flowmeter)
  - Installation of sensors for irrigation control (e.g., flow, irrigation periods, leakage)
  - Installation of sensors for pool control (e.g., volume, treatment, leakage)
  - Selection and installation of lower water use or drought tolerant plants (e.g., native plants)
  - Adaptation or partial rehabilitation of adequate irrigation systems (e.g., drip irrigation)
  - Adaptation or partial rehabilitation of adequate pool distribution systems (e.g., recirculation)
  - Adaptation or partial rehabilitation of pavements with permeability (to lower runoff peaks)
  - Adaptation or partial rehabilitation of a green roof (to lower runoff peaks)

- **Water fixtures**
  - Installation or rehabilitation of fixtures considering the best available water and energy efficiency (both)
  - Installation or rehabilitation of flow restrictors in fixtures
  - Installation or rehabilitation of fixtures considering the best available technology (e.g., dual discharge flush, eco-stop valve)
  - Installation or rehabilitation of sink and bath plugs
  - Adaptation or partial rehabilitation of dual supply systems (i.e., potable and recycled water)
  - Adaptation or partial rehabilitation of heat recovery systems (e.g., bathing)

- **Water appliances**
  - Installation of equipment considering the best available water and energy efficiency (both)
  - Use of equipment labels, preferably with recommendations over consumer behaviour (e.g., to use maximum load)
  - Adaptation or partial rehabilitation of dual supply systems (i.e., hot and cold water)

- **Domestic hot water production**
  - Installation of equipment considering the best available both water and energy efficiency (both)
  - Installation or rehabilitation of pipe thermal insulation
  - Adaptation or partial rehabilitation of efficient hot water delivery systems.

It should be considered that long intervention efficiency measures should include total renovation (i.e., design, installation or rehabilitation) and not partial renovation (i.e., adaptation or partial rehabilitation). Herein, rehabilitation combines replacement and renovation actions.

2.2 Elaborating a documented proposal with technical specifications

Identification of the water and energy efficiency measures allows the auditor to give advice and guidance to the customer/consumer, to the improving of the overall building/household performance and resilience. The expert technician and auditor should be able to present the advantages / disadvantages per efficiency measure, based on the customer/consumer behaviour and expectations, including financial outcome, technical performance and water saving dimensions. Comparisons over the different possible measures and the corresponding advantages/disadvantages should be included in the documented proposal with the identification of the efficiency measures, as well as guidance to the customer/consumer on the quick-win measures in terms of financial turnover.

2.2.1 Financial outcomes, technical performance and water saving dimensions

The identification of the payback time per measure or the calculation of the net present value is important to determine the viability of the investment, only considering the financial outcome. The calculations over the investments should include the total investment, such as material, labour, transport costs, as well as the expected maintenance requirements.

To analyse the overall viability of the measure, the technician expert and auditor should also consider the total time of the project, assumed to be the expected lifespan of the measure. This may be considered as the average time of the measure (e.g., network, pipe, equipment), from implementation until the guarantee of its technical performance or obsolescence.

The payback period (PB) refers to the time needed to repay the initial investment (see the first of the below equations), while the net present value is calculated in terms of currency (second equation). The net present value (NPV) may be relevant to consider in long-term investments. Unlike in the payback period calculation, which is blind to variations in the money value, the net present value may suffer positive effects due to tariff increases or negative effects due to the opposite.

Simple Payback:	$PB = \frac{Investments}{Calculated\ savings\ per\ year}\ [nr\ of\ years]$
Net present value:	$NPV = \frac{Calculated\ savings\ per\ year}{(1+i)^t} - Initial\ investment$

where:
i – the required return or discount rate
t – the number of time periods

The financial gains that can be obtained through the implementation of the water-energy efficiency measures need to be accompanied by the improvements over technical performance. Technical performance should be assessed by the efficiency gains of the measure (e.g., expressed in percentage), the technology upgrade and the level of comfort to the user. Technical performance should be observed under the water-energy nexus, meaning that upgrades in water efficiency should not lead to inefficiencies in energy efficiency, and the other way around.

With respect to the calculated savings, these may differ due to differences in consumer behaviour. Perception of consumer habits may, therefore, help to make good estimations on the expected savings. Likewise, these need to be adequate to the potential real savings, or the calculated paybacks and net present value may be over or under-estimated. Calculations over the water and energy saving estimations should be presented to the customer/consumer, using the corresponding equations (presented in Unit 1). These estimations should not be neglected, given the overall importance of water as a natural resource and of energy efficiency in house bills. In fact, whenever possible, the expected prevented CO_2 emissions should be included in measure comparison.

2.2.2 Documented proposal with technical specifications

The audit process and the identification of water-energy efficiency measures should conduct to a proposal with technical specifications to improve the overall system water-energy performance. As part of the audit report, and as guarantee of the expected outcomes and savings of the implemented efficiency measures, the expert technician and auditor should elaborate the technical specifications required to the implementation of the water-energy efficiency measures.

The main elements that should be included in the technical specifications document are the following:

- **Design, technical and financial aspects**
  - Installation design
  - Technical specifications of the e.g., fixtures, equipment, materials
  - Technical specifications of the construction materials
  - Budget and payment conditions
  - Financial outcomes, technical performance and water saving dimensions.

- **Selection, grant and evaluation requirements**
  - Selection criteria for e.g., fixtures, equipment, materials
  - Grant criteria for e.g., fixtures, equipment, materials
  - Evaluation criteria for e.g., fixtures, equipment, materials.

- **Work execution, term and resources**
  - Reception of the work
  - Work execution term
  - Resources.

The documented proposal should include a blank logbook for the expected interventions considering water-energy efficiency measures. Ideally, the logbook should be used as the building/household water-energy investment and maintenance manual.

Unit 3: Promotion of best practices for the correct use and maintenance of water-energy efficiency systems

Introduction / General description

Through experience and observations during water-energy audits, the expert technician and auditor will gain practical knowledge on the necessary actions need to be undertaken in the verification process and with the implementation of water-energy efficiency measures.

During the different stages of building construction, the technician expert and auditor will verify criteria to the guarantee of system well-functioning, as well as the key steps to perform the necessary measurements and make the identification of the consumption baseline.

Scope – Expected results

At the end of this Unit, the candidate should be able to:

- identify the main care actions in the implementation of water-energy efficiency measures;
- communicate criteria to guarantee regular functioning of the system.

This Unit is constituted by 2 lessons:

LO1: Available hydraulic equipment (fixtures and other final receptacles of water)

LO2: Household appliances

Key words / basic terminology

Consumer counselling, implementation of efficiency measures and analysis of water use equipment.

3.1 Available hydraulic equipment (fixtures and other final receptacles of water)

When performing the necessary measurements and identification of the water-energy consumption baseline, the auditor needs to consider several methodological steps to guarantee similar testing conditions, e.g., prior and next to the water-energy efficiency measures implementation. Likewise, by the time of implementation of efficiency measures, care should be taken to guarantee that implementation is well succeeded.

3.1.1 Identification of the baseline

Undergoing a building/household diagnosis for the identification of the consumption baseline is the first step to find improvements when assessing household water system performance. Benchmarking through standards (e.g., labelling) over the obtained household system performance allows a reference comparison between different households and the identification of the possible measures to upgrade system performance. During the baseline identification, the expert technician and auditor needs to verify if the distribution systems shows leaks and assess the adequacy of performance levels, including the network, fixtures and appliances.

- Pressure
  - Levels of pressure should be adequate to guarantee maximum performance, since under-pressure may be the result of a leak while over-pressure may accelerate system degradation;
  - Appropriate pressure provides maximum performance with respect to user comfort and target flow, as higher pressure may result in higher flow, even with efficient installed devices.

- Flow
  - Testing conditions for flow measuring should be at normal pressure and temperature conditions, and measurements done with calibrated devices;
  - For the sake of comparison, flow rate needs to be measured following the same criteria (e.g., cold water, fully open tap);
  - The use of restrictors needs to be carefully analysed, as their performance may be affected through deposition or losses associated with their use.

- Volume
  - Water volume may be assessed at the flowmeter for baseline characterisation and to quantify flush toilet discharges.

- Label
  - Water efficiency labelling allows consumers to have an easy way to identify the most efficient equipment and is a means to promote its use;
  - Labelling is also a method of providing additional value to manufacturers that develop efficient equipment as it validates high-end performance.

3.1.2 Implementation of efficiency measures

With the characterization of the baseline scenario it is possible to have a correct assessment of the efficiency improvements deployed. The expert technician and auditor usually use experience to analyse the previously gathered data to identify the water efficiency measures. These measures can range from simple behaviour changes to complex leak detection or to change equipment such as washing machines for those with a high-water efficiency labelling.

- Pipe insulation
  - In the scope of water-energy nexus, the use of pipe insulation to the reduction of thermal energy losses leads to reduction of water consumption due to faster temperature increase in the network.

- Flowmeter
  - Flowmeters are used to monitor a liquid flow in a pipe and are divided in two categories: intrusives and non-intrusives. Non-intrusive flowmeters may be used in audits for spot flow measurements, while intrusive flowmeters may be used whenever flow must be monitored on regular basis;
  - The use of flowmeters provides the consumer with detailed data over its water consumption which can translate in the detection of low efficiency equipment, leakages or non-efficient behaviours.

- Flow regulation
  - Regulation of water flows are typical measures identified during audits due to the low cost and high impact that can result from it;
  - Typical measures include: installation of aerators and timers in the faucets, installation of dual flush toilets, valve adjustments, and others.

- Water efficient equipment
  - Replacing equipment for more efficient equivalent is a measure that can generate large water savings, especially if the original equipment is obsolete.
  - Water-using equipment that can usually be replaced include: kitchen equipment, plumbing fixtures, laundry equipment, irrigation equipment, boilers, and others.

- Leak detection
  - The identification of water leakages should be one of the focus of the audits. Water leakages can be identified with the use of flowmeters or directly by inspecting the equipment. Repairing these situations contributes to both improving water efficiency and energy efficiency of the pumping.

- Behavioural measures
  - Behavioural measures are important to assess in an audit as future changes in behaviour can impact water consumption but be difficult to detect. Upon the implementation of an efficiency project, building occupants should be incentivised to implement water efficiency good practices such as: closing faucets, cover swimming pools, take shorter showers, etc.

- Alternative water sources
  - Using alternative water sources reduces the pressure demand on the traditional sources. An example is harvesting rainwater and using it for irrigation of green spaces.

- Precise irrigation
  - The use of sprinklers, hoses and other non-precise methods can because a significant part of water consumption in buildings. In order to reduce water consumption the use of drip-lines or water moisture sensors should be promoted.

3.2 Household appliances

The existing specifications and technical requirements may vary with water utility supplier and amongst different countries. The expert technician and auditor may require monitoring equipment and verification methodologies to conduct a detailed and valid procedure. Certification schemes are usually built upon widely used and accepted methodologies so the use of data from certification such as the energy efficiency labelling can be used to guarantee equipment quality.

3.2.1 Verification of the distribution systems

Water distribution systems at household level can carry different types of water (e.g. rainwater, greywater, network water) and water temperature might also vary, demanding the need for separate cold and hot water networks. These factors imply that the verification of such systems is not linear, as different types of network may require different verification methodologies.

- Cold water
  - The efficiency of the system and the distribution network to be revisited, as the same system design (manifold or branched pipes) may show different efficiency levels in e.g., small or large households, or different storeys.

- Hot water
  - Compatibility between an efficient fixture (e.g., showerhead) needs to be verified with the energy production equipment, as the higher performance level of the fixture may be lower than the one required to start the equipment;
  - The domestic hot water network should be verified in terms of distance to the energy production equipment and the water use point, as there can be water wastes during water heating plus those of reheating water that is back to its initial temperature;
  - The system should be verified in terms of flow velocity adequacy, residence times and adequate materials.

3.2.2 Energy efficiency label

The European Union energy efficiency label aims at providing consumers with a simple benchmarking tool to compare different products. The objective is to promote the purchase of more efficiency equipment to reduce greenhouse gas emissions and energy bills.

The current energy label represents energy efficiency by displaying the energy consumption in a qualitative scale from A^{+++} (most efficient) to G (least efficient). This concept has been driving the energy efficiency market in the European Union and the development of more efficient technologies.

The label is applicable to five groups of products: fridges, dishwashers, washing machines, electronic displays and lamps. For the water-consuming appliances (dishwashers and washing machines), in the bottom part of the label it is represented the estimated yearly consumption of water by using the product. Despite this fact not being directly reflected in the label scale, customers can use the yearly water consumption value and the machine load to compare products and choose the most water efficient one. Figure 3.1 shows a standard label for a washing machine, with an energy label A^{+}, with indication on water consumption in litres per year, total load and other useful information (noise and rinsing efficiency).

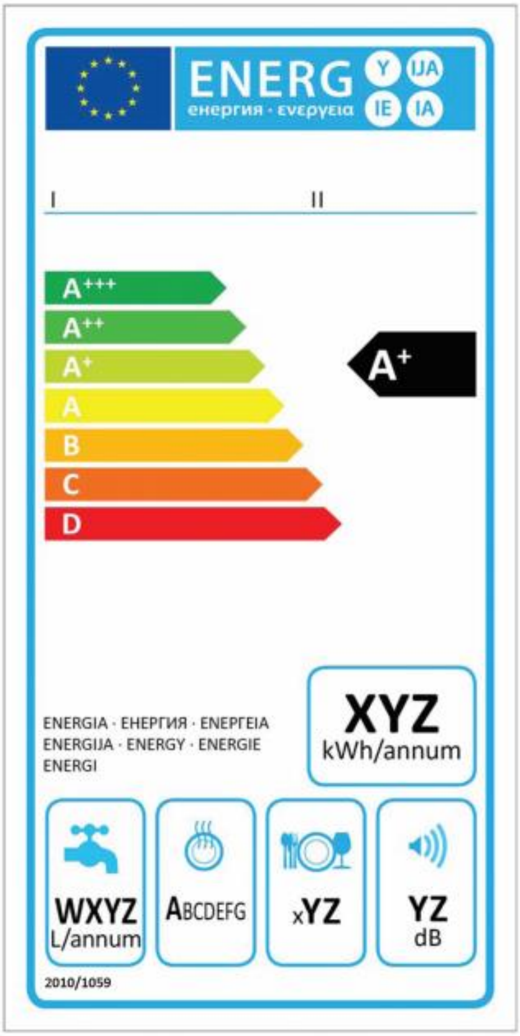

Figure 3.1: European Union's Energy Label – Washing machine

[Source: Commission Delegated Regulation (EU) No 1059/2010 of 28 September 2010]

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SELF-ASSESSMENT QUESTIONS FOR MODULE 4

1.	**In water distribution components in residential buildings, bathing and showering represent:**	
	a) About 15%	
	b) About 25%	
	c) About 40%	√
	d) More than 50%	
2.	**Water auditing to a building or household may apply to:**	
	a) Buildings and households in use	
	b) Buildings and households in the design phase, in use or non-habited	√
	c) Collective use buildings. In the residential sector it does not make sense.	
3.	**Total water consumption associated to each use, in a shower, may depends on (*please choose all the correct answers*):**	
	a) User	√
	b) Flow	√
	c) Pressure of service	√
4.	**To measure flow in a fixture, the expert technician should (*please choose all the correct answers*):**	
	a) Install a flowmeter	√
	b) Calculate flow with the indication of volume and velocity	√
	c) Calculate flow with the formulation: Q=U.S	√
	d) Verify the fixture nominal flow	
5.	**Dimensioning of alternative water uses may depend of:**	
	a) Rainwater harvesting availability	
	b) Possible usage levels by the owner/user of the building/household	
	c) Available area	
	d) All the above criteria	√
6.	**The labelling and performance systems of water efficiency in fixtures:**	
	a) Indicate different reference flows and performance evaluation methodologies	√
	b) Indicate the same reference flows	
	c) Indicate the same performance evaluation methodology	
7.	**Before performing an audit, the expert technician and auditor should:**	
	a) Collect data regarding the building or household, to good characterisation of the site and save time when performing the visit	√
	b) Do nothing, it is only by the time of the visit that it is possible to make the site recognition and undergo the audit	
8.	**A complete water audit should include:**	
	a) The following fundamental component groups, such as water sources and infrastructure, outdoor uses, water fixtures, water appliances and domestic hot water production	√
	b) All water uses, irrespectively of the existing component groups	

	c) All fixtures, appliances and domestic hot water should only be evaluated in an energy audit	
9.	**A complete water audit should provide:**	
	a) Only the payback, as this is the most fundamental criterion to the building/ household owner/user	
	b) A complete financial analysis	
	c) An idea of the type of intervention, as this may be, together with the payback, an important criterion to the building/household owner/user	√
10.	**In the comparison between different measuring equipment, ultra-sound flowmeters:**	
	a) May be more flexible than the mechanical flowmeters, because of being more reliable	
	b) May be more flexible than the mechanical flowmeters, because of being non-invasive	√
	c) Are always less advantageous than the mechanical flowmeters	
	d) Maybe more/less advantageous, depending on the local circumstances	

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