UNIVERSITEIT GENT

Faculty of Bioscience Engineering

Academic year 2015 – 2016

Assessment of water use and re-use in hospitality businesses

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Master's dissertation submitted in the framework of Erasmus+ exchange semester at University of Gent, Faculty of Bioscience Engineering

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Preface

The work developed in the following thesis concerns the analysis of water consumption in five hospitality facilities located in the city of Kortrijk (Belgium) and surroundings.

For each of the five study cases, trend of water consumption, recorded in an observation period lasted from Monday 21st September 2015 to Sunday 20th December 2015, has been analyzed. Moreover, water-using fixtures, equipment and systems currently used have been evaluated.

The aim is to improve water management within facilities, identifying water saving opportunities, considering replacing existing fixtures and equipment with water-efficient models, correct standards of behavior and measures that should be implemented, and considering alternative water sources, as harvested rainwater, for non-potable applications, in order to minimize potable water consumption.

For each of these measures, related savings have been calculated, considering the average water rates in (West) Flanders, achieving the total amount of water that could be saved annually, and consequently, an economic evaluation.

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Abstract

Hospitality businesses consume significant amount of water, essential resource for their services. Due to the increase of water demand in last decades, and to the current situation of water scarcity in many regions of the planet, water management should be improved.

This work presents the case study of five hospitality facilities located in the city of Kortrijk (Belgium) and surroundings, whose water consumption have been registered for three months, and evaluated. For each of them, fixtures and equipment used and current water management have been analysed, identifying water saving opportunities, considering replacing existing fixtures and equipment, implementing correct standards of behaviour and considering alternative water sources for non-potable applications.

The work analyses the impact of these actions on consumption, and their economic profitability. Results show that significant savings can be reached acting on sanitary fixtures and kitchen equipment, as well as implementing corrects practices: in each study case, a substantial percentage of current average water consumption could be saved, in some cases more than half. Moreover, for each business, potential rainwater harvested has been calculated, showing that it represents a conspicuous percentage of city water currently used for non-potable applications as irrigation and domestic purposes.

Introduction

Water is a finite and vulnerable resource, nowadays considered an economic good. It is well known that a crisis of water resources is taking place all over the world as more than 2 billion people lack access to clean drinking water and a large share of world population will face severe water scarcity by next decades. Moreover, in last years, due to population and economic growth, changes in lifestyle and higher standards of living, global water use has tripled. Besides, the problem is exacerbated by degrading water quality, as over half of the water available for human use is polluted, and climate change, manifested through reduction of precipitation levels and increased frequency of drought.

The purpose of the thesis is part of a broader concept: developing green management standards that hospitality businesses should implement. In particular, the whole work arises from the need to optimize and improve water consumption within hospitality facilities, presenting key water measures that businesses should implement. The work deals with the case of five businesses in the city of Kortrijk (Belgium) and surroundings, analyzing for each of them currently situation of water management in order to understand the trend of water consumption, and identify saving water standards and technical improvements that should be put in practice.

The work consists of three sections. The first, Chapter 1, is a literature study reporting data about water use in Europe and in the world, concerning agricultural, industrial and domestic sector, where the highly variable consumption within different countries is underlined. Moreover, first section focuses on water use in hospitality sector, lingering on the concept of Green Management in hospitality businesses, with particular reference to restaurants, mentioning examples that put in practice green management standards.

The second section regards materials and methods and is made up of chapters 2, 3 and 4. In the second chapter study cases are presented and the action plan implemented is explained: first step consists in collecting data about water consumption in facilities analysed during the monitoring period of three months, in order gather available information about the average consumption and to identify peaks due to particular events. Next phase is touring the facilities inventorying current water using fixtures, equipment and systems, studying their characteristics in order to understand how businesses use water, and how they can reduce waste. At the same time, personnel and managers have been interviewed to understand how they use to operate, and for what purposes they use water. Once these information are available, it is possible to set goals that each facility can achieve, calculating costs, potential savings and simple payback.

In the third chapter different measures, aimed to reduce water losses and to optimize water management, are explained, focusing on three key factors. The first is the importance of monitoring, in order to manage water, reduce waste and identify possible leaks. The second is the increasing of water efficiency through more efficient equipment, systems, fixtures and processes, for this purpose sanitary and commercial equipment has been analyzed, reported consumption of different types of fixtures commonly used in hospitality facilities. The third is the importance of implementing good standards of behavior, educating employees and occupants and putting in place correct standards regarding kitchen, restroom, laundry and landscaping.

In fourth chapter alternative water sources, including rainwater and treated greywater, are considered for non-potable applications. Treatment technologies, systems and quality of rainwater and greywater are explained, focusing on domestic harvesting. Besides, for each of these sources, have been reported examples of facilitates that are using alternative water source in non-potable applications, in order to make water management more efficient and minimizing potable water consumption.

Finally, the third section, made up of Chapter 5, discusses results of the analysis. In particular, for each of the five study cases, trend of water consumption, extrapolated in an observation period lasted from Monday 21st September 2015 to Sunday 20th December 2015, is analyzed. Thus, water using fixtures, equipment and systems currently used are evaluated and their consumptions have been compared with more efficient one, considering retrofitting or replacing existing service equipment with water-efficient models, with a relatively short payback period. For each facility, correct standards of behavior that should be adopted are identified, starting from sensitization of guests and employees, as well as good practices concerning kitchen, restroom, laundry and landscaping. Moreover, considering alternative water source, focusing the attention on rainwater reuse, possible utilizations are considered, calculating potential quantity that can be harvested. For each of these measures, aimed to optimize water management, related savings are calculated, considering the average water rates in (West) Flanders. In this way, knowing the total amount of water that could be saved annually, it is possible to do an economic evaluation, identifying and assigning a monetary value to retrofit and replacing in terms of costs and benefits.

Literature study

Chapter 1: Water as a finite and vulnerable resource. Its use in hospitality businesses

This first chapter contains an introduction to the problem of water crisis that is considered by now a global issue since more than one billion people lack access to clean drinking water, and only 1% of water on the planet is available for consumption by humans. Particularly, in the first paragraph have been reported data about water use in Europe and, more generally, in the world. The second paragraph focuses on water use in hospitality sector, distinguishing direct and indirect water use; moreover, it has been explained the concept of Green Management in hospitality businesses, with particular reference to restaurants, mentioning examples that put in practice green management standards, pointing out results in terms of water saving.

Finally, the last part of the chapter makes up an introduction to the whole work that deals with the case of five businesses in the city of Kortrijk (Belgium) and environs. For each of them, currently situation of water management has been analyzed in order to understand the trend of water consumption, and identify saving water standards and technical improvements to conserve water, that should be put in practice.

1.1 Clean water crisis: a global issue

At the World Summit in Rio de Janeiro in 1992, one of the four Dublin Principles declared water, for the first time, an "economic good". It means that, being an economic and social good, water has a price since it is collected from a source. [1] Moreover, water is a finite and vulnerable resource that should be managed in a rational manner, through an efficient and reasonable use, encouraging saving and preservation of this resource. In fact, water, not only satisfies world population needs, but also supports development and wellness through agriculture, industry, transports, and tourism.

However, a crisis of water resources is taking place all over the world: indeed more than one billion people lack access to clean drinking water and a large share of world population will face severe water scarcity by next decades. Water scarcity is due also to the increase of population, in fact as the population grows there will be proportionally less water available per capita. The problem regards particularly areas with low rainfall and high population density, as Central and West Asia and North Africa. [2] Moreover, less than 1% of water on the planet is available for consumption by humans. Particularly, freshwater constitutes a very small portion of all water on the planet: while nearly 70% of the world is covered by water, only 2.5% of it is fresh, but just 1% is easily accessible, with much of it that is frozen in glaciers or polar ice caps. The rest is saline and ocean-based. [3]

1.1.1 Causes and issues related to water

In the last 50 year, global water use has tripled, due to population and economic growth, changes in lifestyle with higher standards of living, urbanisation, technologies and international trade, and expansion of water supply systems. Simply put, while water use is increasing, available water resources is declining in many regions because of the depletion of non-renewable fossil water resources (both groundwater and glacial ice), pollution of water bodies and groundwater sources, and climate change leading to declining precipitation levels and increased frequency of drought. [4]

Moreover, the growth of urban areas has several effects on the water cycle, in fact hydrological system is altered by change in land use. Urban development usually leads to soil sealing by asphalt and concrete, meaning that water cannot seep naturally into the earth. However, climate change has a more indirect effect on water quantity than land use change. It has been estimated that the reduction of water availability will be due mainly to the growth in temperature (between 1°C and 3.5°C) and the increase of rainfall in Northern Europe and decrease in the Southern. Particularly, the main negative effects of climate change will manifest mainly in drier regions (IPCC, 1996).

Substantially, issues related to water are:

- *Increasing water stress and scarcity*: by 2025, more than one billion people will be living in regions with absolute water scarcity. By 2050, almost 4 billion people will be living in river basins under severe water stress;
- *Degrading water quality and stringent regulations*: over half of the water available for human use is polluted. To obviate this, regulations are constantly evolving, and more stringent standards are being adopted throughout the world;

- *Increased demand in developing regions*: 80% of global population growth is expected to occur in developing countries by 2020. Water demand is projected to increase by 55% globally and by over 80% in BRICS countries (Brazil, Russia, India, China and South Africa) between 2000 and 2050. [5]

1.1.2 Water use by sectors in Europe and in the world

The FAO distinguishes agricultural, domestic and industrial fresh water consumption, as all the economic sectors require water for their development. On average, 70% of water use is for agriculture, 20% for industrial and 10% for domestic purpose, including households, municipalities, commercial establishments and public services. [4] However, there are several differences among countries concerning water use, because they use it in different ways and quantities in each sector. Particularly, Southern European Countries use the largest percentages of abstracted water for agriculture: irrigation represents the most significant use of water in these Countries, being almost 100%. Western and Northern Countries, use the largest percentages of abstracted water for urban needs and energy production. They are the largest users of water for energy production: in particular Belgium, Germany and Estonia, where more than half of the abstracted water is used for energy production and generally, industries spend the most significant part of water resources in cooling processes. [6] Fig. 1.1 provides data about sectoral use of water in Europe.

The different consumption of water within countries in the world is due also to the fresh water availability that is unevenly distributed between countries: for instance, daily domestic water use in Bhutan is 12 L per capita (in 2000) and 1226 L (in 2005) per capita in Australia. On average, domestic water use is 160 L per capita per day. [4] In Italy, in spite of water consumption for civil use accounts the lower percentage compared to the other sectors (only 15% of total use, 60% is for agriculture and 25% for industrial purpose), in this sector is recorded the higher consumption of drinking water. [7]

Concerning industrial water use, Eurostat estimated that, on average, 40% of water abstracted in Europe is used for industrial purposes, particularly during the production processes. Above all, industry is the major water polluted, with only 60% of industrial wastewater that is subjected to treatment before discharge. Particularly, Eurostat assessed that the most of the water in the industrial sector, is used for the production and the distribution of electricity.

Finally, concerning hospitality sector, it is predicted that, by 2020, tourism's contribution to water use will significantly grow due to increased tourist number, higher hotel standards and increased water-intensity of tourism activities. Nevertheless, in comparison to other economic sectors, such as agriculture, water use in hospitality sector is still under investigated, despite fresh water is essential for it, since it is used for both direct and indirect purposes, and is essential for the improvement of these kind of activities. [4]

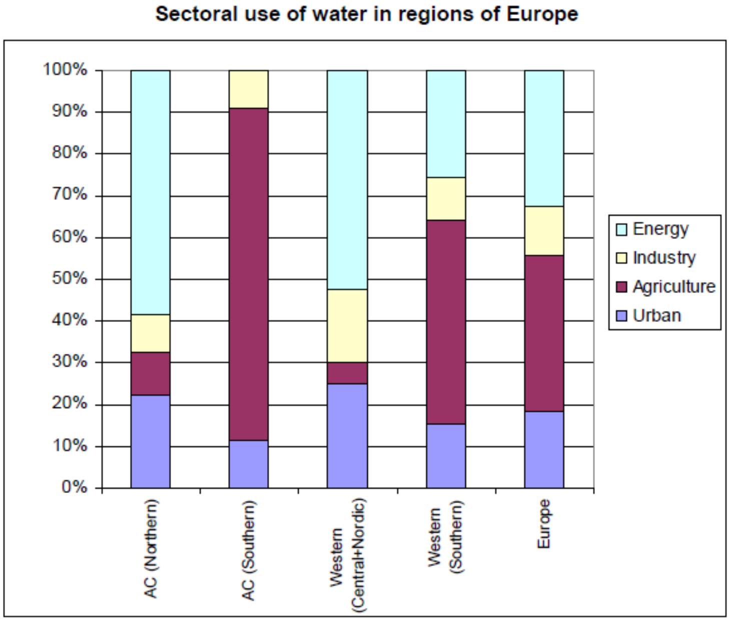

Fig. 1.1: Sectoral use of water in regions of Europe.

Source: New Cronos (Eurostat-OECD JQ2002)

1.2 Businesses and tourism water consumption

As hospitality businesses consume significant quantities of natural resources, it is important to study the complex relationship between water and tourism issues in order to identify future management standards and good practices. It is important underline that tourists use more water on holiday, on average 300 L per day (direct water use), than at home (160 L per capita). Reasons why people use more water as tourists, concern hygienic purposes in accommodation (daily room cleaning; daily laundry), recreational activities (requiring water intensive maintenance of green areas and swimming pools), more elaborate food preparation. [8]

Gössing estimated tourism to be responsible for the use of 9.274 million m^3 of fresh water in 2000, representing roughly 3.4% of domestic water use and 0.3% of total water use globally. Moreover, there are two important aspects concerning water consumption in hospitality businesses: the first is that pick of clients often arrives during the dry season, when rainfall drops to a minimum and water availability is restricted, the second is the influence on water quality. Exacerbating the situation is lack of sewage treatment systems. For instance, in Mediterranean countries, only half of the sewage networks are actually connected to wastewater treatment facilities with the rest discharged into the sea, while 48% of the largest coastal cities have no sewage treatment systems. [4]

The American Water Works Association, through a study concerning hospitality businesses in United Stated, assessed that 15% of the total water used in commercial facilities, is spent in hospitality and food services. Moreover, it has been shown that most of the water in restaurants is used in kitchen (52%), because of the equipment needed for food preparation and cleaning, and in restrooms (31%), for hygienic purposes.

1.2.1 Direct and Indirect Water use

Fresh water is an essential resource for hospitality businesses, both for direct and indirect water use. About the first the higher consumptions regard washing or using toilet, participating in activities as ski or golf (snowmaking and irrigation), using spa, wellness areas or swimming pools. Moreover, fresh water is also used to maintain the gardens and landscaping of hotels and restaurants. About indirect water use, it regards water embodied in tourism infrastructure development, food and fuel production. [4]

Because of the complexity of the issue, it is important studying the problem differentiating direct water use, that includes water consumed per tourist per day, which is usually restricted to accommodation, and indirect water use, namely water needed for the production of infrastructure, fuels and foodstuffs, that is still poorly understood. [9]

Concerning direct use, the literature suggests water consumption rates in a range between 84 and 2000 L per tourist per day. However in higher-standard accommodations there is tendency to consume significantly higher water volumes, for instance in hotels with spas and large and multiple swimming pools or landscape grounds requiring irrigation. Moreover, sport and health centres involve higher laundry volumes per guest per day. Of course, water use is influenced by various factors, as geographical location of accommodation, hotel structure and comfort standards.

Regarding activities, the higher value for activities relates to golf, which appears to be the most water-intensive activity: consumption of water by golf varies considerably depending on soils, climate and golf course size.

For instance, a standard golf course may have an annual consumption of 80.000 m^3 – 100.000 m^3 in the North of France, and 150.000 m^3 – 200.000 m^3 in Southern France. Much higher values can be found in dry and warm climates. [4], [9]

Concerning infrastructure, as indirect water use, it can be mentioned that use and construction of buildings is responsible for 17% of water consumption worldwide. Particularly, concrete is the second most consumed material in the world after water, and water consumption for cement hydration is approximately one billion m^3 of water. Literature suggests that the major end uses of concrete are residential buildings (31%), highway and roads (26%) and industrial and commercial buildings (18%). [4]

Considerable amounts of water are also embodied in food consumption. UNESCO reports, for instance, that depending on local climate, 1 kg of wheat requires 400-2000 L of water and it takes 1000 to 20.000 L of water to produce one kg of meat, depending on animal, feed and management. Therefore, it has been assessed that daily water requirements to support human diets range from 2000 to 5000 L of water per person per day, depending on their diet and lifestyle, with an estimate of 1 L of water for 1 Kcal of food. [4] Particularly, a typical diet of a person from USA requires about 5400 L of water in the form of evapotranspiration per day, while a vegetarian diet is responsible for the consumption of 2600 L of water per day. It has been estimated that people need 70 times more water to grow food, than for domestic purposes, considering a domestic requirement of 50 L per person per day and a food requirement of 3500 L per person per day. In addition, the large majority (up to 90%) of the water required for domestic purposes is returned after use as wastewater and can be recycled, while most of the water (40–90%) provided to agriculture is consumed (evapotranspired) and cannot be re-used.[2]

Finally, regarding fuel use it should be emphasized that energy and water are closely related, as water is needed for energy production, and, in the same way, energy is used for water production (pumping, transport, treatment, desalination). For instance, Worldwatch Institute reports that it takes 18 L of water to produce 1 L of gasoline. So, using less water means also using less energy, because it takes a lot of electricity to pump water from a water source, purify it for our use, distribute it to our homes and businesses, and clean it again after we have used it.

1.2.2 The concept of Green Management

As commercial businesses use a significant amount of municipally supplied water, it is important apply water-efficient practices, to achieve and sustain long-term water savings.

The aim of this work is, in fact, to propose and identify good practices and standards concerning water management. Actually, the purpose of the thesis is part of a broader concept: developing green management standards that hospitality businesses can implement. This notion includes three facets: green foods, green environment and equipment, and green management and social responsibility. This work will focus on the latter, as hospitality sector continues to grow, and, particularly, restaurants are world's largest energy users: they use almost five times more energy per square foot that any other type of commercial building.[10] Therefore, the need of so-called green restaurants has been developed.

The concept of green is broader than environmental protection: the latter concerns waste and pollution, while green industry considers recycling, low pollutions and energy conservation throughout the production, usage and disposal cycle. The concept of green is, thus, wide, and interests particularly three areas in which good practices can be implemented: green food (organic and local), green giving (donating to green projects), and green action that includes recycling, green construction and energy and water management. [10]

As these kind of problem are becoming more and more current, the Green Table Network (a not-for-profit organization managed by the GLOBE Group, that is dedicated to bringing sustainability strategies and greener business practices, to the restaurant and food service industry) has identified, between guidelines for the restaurant industry, the improvement of energy-efficiency and water-saving.[10]

In fact, water-energy nexus is now recognised as a critical concept that highlights the interdependencies between water and energy production and consumption. Therefore, water should no longer be considered as an individual cost, rather as a cost linked to energy.

Through good practices, businesses could reduce their impact on the environment, saving energy and water, and publicizing these efforts to customers.

Particularly Davies and Konisky supported that food industry impacts the environment in three ways:

- Direct environmental impacts, relating energy consumption, solid waste generation, water emissions;
- Upstream environmental impacts, relating pollution produced by suppliers, including pesticide residues, animal waste, and food safety problems during production;
- Finally, downstream environmental impacts, concerning linkages between operators in these industries and consumer behaviour.[10]

It can be seen, thus, that water saving represents one of the fundamental green concepts, that can be reached not only through environmental management policies, but also through education for employees and consumers, and social responsibility.

1.2.3 Example of green management and water saving

Below, have been reported examples of businesses that have put into practice environmental management as business philosophy, through measures aimed not only to save water, but in some cases also to increase electricity efficiency and to improve waste management.

1.2.3.1 McDonald's example [11]

In 2012, McDonald's has opened Australia's first Green Star accredited restaurant at Kilsyth in Victoria. The Kilsyth restaurant supports many sustainable initiatives including energy efficient lighting and air conditioning, solar panels, rainwater harvesting and the use of recycled concrete and steel. Some initiatives put into effect, regard reduction of energy use: lux level sensors, attached to the dimmer system, have been installed to control the dining room lighting. The sensors adjust the level of the internal lighting, comparing it with the levels of natural light available; moreover waste heat from the kitchen or absorbed heat from the ambient air, are used to heat hot water – reducing overall energy consumption by up to 7%.

Regarding waste, a new solid waste management strategy is currently being developed.

Finally, concerning water use, different ways to reduce water usage have been implemented. Rainwater tanks are standard for all new restaurants: rainwater is collected and used for irrigation and toilet flushing. Time flow taps are used in all new and re-modelled restaurants, shuting off after seven seconds, and saving approximately 100 to 200 liters of water per day. Besides, all new restaurants use water efficient tapware and sanitary ware, including time flow taps and dual flush toilets. Water efficient spray guns are used for washing up in the kitchen, reducing water use by approximately 60% compared to previous spray guns.
Finally, new landscape design guidelines encourage the planting of native and drought resistant plants.

1.2.3.2 The case of study of a Spanish hotel. The advantage of retrofitting equipment [12]

An interesting work concerns the case of a hotel in the city of Zaragoza (Spain): it has been shown that retrofitting equipment with water-saving technologies, reduces water use. Particularly, it has been demonstrated that with small investments, it can be achieved a significant reduction of the amount of water consumed, and, consequently, an economic profit. The business considered, Silken Reino de Aragón Hotel, is a four-star hotel with 117 rooms and 191 beds, and has a clientele mainly associated with business travels. In 2008, the daily water consumption per guest before retrofitting, was, on average, of 396.5 L. In 2009 during the renovation of the hotel, taps with ecological cartridges and dual flow systems were installed, and aerators limiting the flow to 6 L/min were fitted to the washbasins and bidets. In addition, discs limiting the flow to 9 L/min were fitted in the showers. Some months later, further retrofitting took place in the kitchen, consisting of replacing pre-wash showerheads with others limiting the flow to 9 L/min, and replacing the devices controlling the flow of water to the dishwashing station.
Through linear regression models, the impact of the retrofit on the hotel's water consumption has been evaluated. Results showed that in bedrooms and public area, has been achieved a reduction of about 3402 L per day in average cold water consumption. Moreover, the impact of the retrofit on hot water consumption was a decrease of 2767 L a day, and an additional decrease in consumption per guest of 22 L/day. The main impact of the kitchen retrofit was on daily cold water consumption. However, both retrofits, in the

kitchen and in the bedrooms, had an important effect on the amount of water used, with reductions of 2402 and 5750 L a day, respectively. Overall, results showed a 21.5% reduction in total water consumption (17.6% in cold water and 33.2% in hot) after the retrofits, and the decrease of daily water consumption per guest.
Concerning costs and benefits, it has been estimated that retrofits implied reduction on costs for the consumption of water of €88,369, namely an average annual reduction of €12.207 (considering also the decrease in electricity and gas use).

1.2.3.3 An example of greywater re-use in a hotel in Mallorca Island [13]

As Mallorca is part of one of the Mediterranean water-stressed regions, the interest in water re-use has become more and more growing. Particularly, water used in bathtubs, showers, hand-washing basins, laundry machines, kitchen sinks, commonly called greywater, has low content of pollutants, so it can be used to flush the toilets. Taking this into account, a project, studying a three-stars hotel with 81 rooms, was performed. Its clientele consists mainly in foreign visitors and summer is usually the busiest period.
The study focuses on an indoor greywater recycling system to flush toilets in the hotel. It has been estimated that water used to flush the toilets represents 23% of the average sewage water consumption. Therefore, the work demonstrates that toilet flushing can be carried out with non-potable water, achieving a significant saving of water resources. In fact, a 14-year payback period was calculated, considering that the system would have been active only 7 months a year, due to the trend of tourists arrivals.

1.3 Water Management Planning

The aim of this work is to propose and identify good practices and standards concerning water management, in order to reach the following goals:

- Reducing of water use and losses;
- Increasing water efficiency of fixtures, equipment, systems, and processes.
- Educating employees and guests about water efficiency to encourage water-saving behaviors;

- Reusing onsite alternative water that would otherwise be discarded or discharged to the sewer (e.g., reusing treated gray water or rainwater). [14]

Therefore, the following work consisted in analysing water consumption in five Belgian businesses:

- Chip shop Bossuwé, located in Kortrijkstraat 396, Wevelgem;
- Café Balthazar, located in Paleisstraat 20, Kortrijk;
- Hotel Messeyne, located in Groeningestraat 17, Kortrijk;
- Restaurant Lindenhof, located in Vichtesteenweg 280, Deerlijk;
- Restaurant Koevert, located in Krevelstraat 1, Kerkhove.

For each of these businesses, for three months, water consumption has been monitored, in order to achieve daily consumption and to establish a water use baseline, analysing consumption trend during observation period. Thus, in order to manage water, it was necessary first measure its use, also during closing days in order to measure the amount of water used by actual equipment and systems. Once data are available, a water management plan can be developed and put in place. Second step has been to understand how specific fixtures, equipment, systems, processes and behaviour, contribute to the general facility water use, namely identifying all the major water using fixtures, in order to realize how a facility can improve its water efficiency.

Next step has been to create an action plan: it should determine which practices could be implemented at the facility to achieve water management goals. This phase concerns calculation of costs and potential saving, and also of simple payback.

Finally, alternative resources have been considered, as reuse of greywater, or rainwater captured from building roofs, that provide new sources of water.

Materials and methods

Chapter 2: The Action Plan developed for five study cases to ensure water efficiency

The chapter is an introduction to the work developed, where single phases implemented for the five study cases have been described.

After having briefly explained the Action Plan implemented, in the following chapter initial phases have been studied in deep. In particular, first step was gathering available information to investigate about water use and in order to identify peaks of consumption due to particular events, having a full picture about water consumption trend, during monitoring period of three months.

Second phase consisted of realizing a sort of inventory, in which characteristics of equipment and systems, currently used in each facility, have been collected. Therefore, the aim is, identifying inefficiencies and behavior patterns that could be improved, and comprehending if it is necessary to replace existing service equipment with water-efficient models, with a relatively short payback period.

2.1 The importance of an Action Plan

In order to understand how water is managed in the facilities considered, it is necessary to set out some fundamental steps, through which the water supply sustainability can be ensured. Particularly, developing a water management policy and implementing effective practices, helps managers to understand how much water their facilities use, and which processes require the most water.

As has been said in the previous chapter, the cases of study considered in this work, are five businesses located in Belgium (Kortrijk and surroundings). Of course, in each of the facility considered, the daily consumption of water, as well as energy and the daily amount of waste produced, are due to the different services offered and activities performed. For this reason, each building can adopt a particular policy to optimize water consumption and identify potential water-saving opportunities, as improvements in equipment and

operational practices. Through these evaluations and taking into account various factors, results of a careful field study, each business will be studied in order to understand how they can significantly reduce water use through water efficient fixtures, technologies and techniques, developing an action plan specific for each of them.
Literature suggests that implementing water-efficient practices in commercial facilities, can decrease operating costs by approximately 11% and energy and water use by 10% and 15%, respectively [15], also because food service facilities use hot water for many tasks, so, reducing water use, can provide real benefits by decreasing energy bills.

2.1.1 The structure and key phases of an efficient Action Plan [14]

The Action Plan described below, has been developed by WaterSense (a partnership sponsored by the U.S. Environmental Protection Agency), in order to identify water-efficiency management practices that commercial facilities owners can implement.
Particularly, this work focuses on the actual situation about water management and equipment used in businesses considered, and quantifies, thanks to data provided, how much water is currently used and how it could be saved, implementing simple behavioral practices and replacing the current equipment with new and more efficient ones. Besides, it has been considered an alternative source of water, rainwater, that could be used for several purposes, particularly for outdoor demand and flushing of toilets, and advantages, in terms of water saved and money, have been calculated.
First step, to understand how facilities use water, was identify all sources of water, but in this case all businesses considered are supplied by municipal potable water. Afterwards, collecting data, during a monitoring period of three months, was useful in order to have information about the average consumption that represents a reference point for the work.
Next phase was inventorying water using fixtures, equipment and systems, in order to understand how businesses use water, and how they can reduce waste. Therefore, touring the facilities, every kind of equipment has been registered, and characteristics have been studied. At the same time, personnel and managers have been interviewed to understand how they use to operate, and for what purposes they use water. Once these information were available, it was passible beginning the work, and setting goals that each facility can achieve, calculating costs, potential savings and simple payback.
Of course, a key role, in order to get significant results, is the behaviour of people managing water, such like owners, personnel, but above all customers; therefore it is

necessary, not only equipping facilities with high-grade technologies, but also educating to an efficient use of water.

2.2 Collecting consumption data

To improve water management in each business, the first step is having available information about general water use patterns. This information can be used to reach a more detailed investigation of facility water use. It is necessary also to determine how many days the facilities are operating per week and when fluctuations in water use may be expected (most of times, they occur during the weekend due to increase of customers flow, or due to parties organized in the businesses considered). For each business, the water meter has been identified, and it has been noted for which uses it is dedicated to (e.g. irrigation, indoor water use).

Fig. 2.1: Water meter

For three months, data have been collected every day[1], monitoring facilities water use, through existing water meters, in order to understand how much facilities water use costs and to provide owners information to better manage their facility water use.

Also, it has been observed that each business uses the same type of meter to determine water consumption: positive displacement meter. This type is very common for small businesses, because, thanks to its high accuracy, permits to measure peak flows.

The period analyzed lasted from 21st September 2015 to 20th December 2015, a total of $T = 91$ days. However, records do not exist for every day, so only global data are available for some periods, especially weekends.

This is a key phase, as water consumption data can help to evaluate trends in water use, to allow projections of future water demands, to assess water use performance and to ascertain the impact of any water conservation measures. In Chap. 5, graphs, concerning daily consumption of each business, have been reported in order to give an immediate vision of the situation during the monitoring period.

[1] Note that, starting from the third week of monitoring, data from Hotel Messeyne and Balthazar have been provided once a week, due to organizational problems within the businesses.

2.3 Inventorying Water- Using Fixtures, Equipment, Systems, and Processes

Commercial facilities considered have, depending on their size and their services, sanitary fixtures or equipment, like toilets, urinals, laundry, and, of course, fixtures and equipment in the kitchen.

In order to identify the current situation concerning water use management for each business, it is necessary analyse what kind of fixtures, equipment, systems and behaviour are implemented, and how they can influence water consumption. In fact, studying them, it is possible to identify how a facility can improve its water efficiency. For this purpose, facilities have been toured, inventorying water using equipment, and verifying water use, in order to identify potential reduction opportunities. During the inspection personnel that manage water using systems or equipment, has been interviewed to verify water use.

It has been noted that nearly all businesses considered, have table service and at least a dishwasher (except the frituur Bossuwè). Besides, every type of commercial facilities considered have at least some sanitary fixtures or equipment, including toilets, urinals, faucets and Hotel Messeyne has also showerheads and bathtubs. It is important to underline that none of them use to harvest rainwater.

Below, have been shown features of equipment and fixtures for the businesses considered. More detailed information about equipment brands, models and features, are reported in Table 2.1, 2.2 and 2.3.

2.3.1 First Case Study: Bossuwé

Facility type: Chip shop

Location: Wevelgem, Belgium

Potential capacity: 50 seats

Building Size: 120 square metres

Fig. 2.2: Bossuwè

Bossuwè is a typical Belgian chip shop, opened since February 2014. As the owner confirmed, peak customers occurs at lunchtime (from 11:00 to 13:00) during the day, between Friday and Saturday during the week, instead the peak during the year occurs during school holidays and summer period (June, July and August). The business is closed on Sunday, and it is open every day from 11:00 to 14:00 and in the afternoon from 17:30 to 22:00. In the business there are not dishwashers, and number of employees is 4 during the week, and 5 on Friday and Saturday.

Here, the indoor demand consists of uses for sanitary, food preparation and cleaning purposes. On the contrary, there is not outdoor use at this site. The average daily indoor water use in Bossuwé, during the monitoring period, is 0.619 m^3 per day.

During the visit, it has been observed that water use is mainly due to sanitary uses and cleaning purposes. The first concern utilization of hand sink with single handle faucet, made with single-lever control, to adjust water flow and water temperature, and two toilets (one for gents and the other one for ladies) equipped with double flushing. The second regard use of double compartment sink for washing pots and vegetables during food preparation. The sink is equipped with a faucet constituted by a long hose and multi-option spray head (Fig 2.3). In the kitchen there are also a small hand sink used only by personnel with sensor (Fig. 2.4) and a water cooler (Fig. 2.5).

Fig. 2.3: Pre-rinse spray used in Bossuwè

Fig. 2.4: Hand sink used in Bossuwè

Fig. 2.5: Water cooler used in Bossuwè

2.3.2 Second Case Study: Balthazar

Facility type: Caffè, restaurant

Location: Kortrijk, Belgium

Potential capacity: 45 seats in the restaurant, 40 seats upstairs, maximum 100 people in the pub

Fig. 2.6: Balthazar

Café Balthazar is a commercial facility located in the city centre of Kortrijk, that usually works as a restaurant during lunchtime, and a pub during the evening. Overall, peak customers is constant during the year, but occurs between Saturday and Sunday during the week. On average, every day arrive 70 people to the restaurant at lunchtime, and more than 300 in the evening. The business is closed on Tuesday and Wednesday, and it is open every day from 11:00 to 14:00 and in the afternoon from 18:00 to 22:00. The two-storey building holds, on the ground floor, the kitchen, the dining room and another room with the bar and some tables; upstairs there are rooms mainly used for family celebrations, business lunches or meetings. Touring the facility it has been noted that the indoor demand consists of uses for sanitary, food preparation, cooling drinks and cleaning purposes. The average daily indoor water use in Balthazar, during the monitoring period, is 2.43 m^3 per day.

Fig. 2.7: Single handle faucets in bathroom

Touring the facility, equipment and systems have been photographed and registered, in order to have a full picture of the situation. Particularly, in the bathrooms are installed hand sinks with single handle faucet (Fig. 2.7), made with single-lever control, to adjust water flow and water temperature, toilets equipped with double flushing in the ladies'toilets, and urinals with sensors in gents' toilets. Besides, in the basement, there are a water softener (to make water more compatible with soap and extends the lifetime of plumbing, preventing the formation of limestone) and a draft beer cooler. In the kitchen there are a small hand sink used by personnel, another small sink used to wash vegetables or food in general, a bigger sink equipped with a faucet constituted by a long hose and multi-option spray head, food warming equipment, two dishwashers (four and two years old) and two ice machines (a small one and a bigger one upstairs). In the bar there is a double compartment sink for washing pots, that is filled about 4 times per day (Fig. 2.8).

Fig. 2.8: Double compartment sink located in the bar

2.3.3 Third Case Study: Hotel Messeyne

Facility type: Hotel

Location: Kortrijk, Belgium

Potential capacity: 26 rooms, 40 seats in the restaurant

Building size: 900 m^2

Fig. 2.9: Hotel Messeyne

This hotel, opened since 2003, is a four-star hotel built on three levels, with 26 rooms, in the city center of Kortrijk. Its clientele is mainly associated with business travel; in fact, occupancy is significantly lower in holiday periods, especially in August, when hotel is closed for two weeks. However, customers flow is quite constant during the rest of the year because it is mainly a business hotel.

The hotel has a restaurant seating 40 people, two meeting rooms equipped for events holding up to 35 and 80 people, a fitness room, a sauna and hammam not taken into account, due to lack of data. The hotel does not have a swimming pool or garden, and the laundry service consists in a wash machine and a dryer.

Fig. 2.10: Body spray

Data from Hotel Messeyne have been collected every day for the first two weeks, and once a week until December. The average weekly indoor water use during the monitoring period, is 7.61 m^3 per week.

Fig. 2.11: Pre-rinse spray used in the kitchen

Fig. 2.12: Double handle faucet located in the kitchen

Each room is different from the others, so randomly two rooms have been visited and characteristics have been recorded. In both rooms there are a double sink with single handle faucets and toilet equipped with double flushing. Then, in the first room, there are both the bathtub, with a single-handled tub faucet to control the flow of the water and another device to control the water temperature (Fig.2.10), and the shower with a double rain shower and the same single-handled faucet. In the other room there is only the bathtub with the faucet explained before, equipped with a single rain shower, to serve also as shower. Regarding public toilets in the hotel, used by restaurant customers, there are toilets equipped with double flushing in the ladies'toilets, and urinals with sensors in gents' toilets. In both hand sinks with single handle faucet are installed. Equipment for water use in the kitchen have been also investigated: a single dishwasher is used by the staff, and two sinks to clean. The first one has a single compartment and is equipped with a faucet constituted by a long hose and multi-option spray head (Fig.2.11), and the second one with a double compartment and double handle faucet (Fig 2.12). Finally, the laundry is fitted out with a washmachine and a dryer for linen used by occupants of the rooms and customers of the restaurant.

2.3.4 Fourth Case Study: Restaurant Lindenhof

Facility type: Restaurant

Location: Deerlijk, Belgium

Potential capacity: 40 seats in the restaurant, 300 seats in the bigger hall and 200 in the smaller

Building Size: 1200 m^2

Fig. 2.13: Lindenhof

The fourth case study is Lindenhof, located not far from Kortrijk. The large structure holds a restaurant, a bar and banquet rooms used often during the weekend, for family celebrations or marriages; in fact, as it is possible to see from the graphs, higher water consumptions occur between Friday and Sunday. The facility is closed on Monday, and as the owner explained there is not peaks, but customers flow is variable during the year. Thanks to conspicuous availability of data, that steadily every day have been recorded, it was possible leading an accurate analysis about water use in this business. Particularly, it can be observed that the average daily water use at the site is approximately 2.85 m^3 per day.

Fig. 2.14: Hand sink used in Lindenhof

In spite of the presence of the garden, the demand consists of indoor demand for use of sanitary, food preparation and cleaning purposes, as there is not an irrigation system and garden is watered only by rainwater. Therefore, no water consumption due to outdoor use is recorded.

Touring the facility, it has been observed that, due to the large size of the building, there are a lot of water-using fixtures, equipment and systems for water use. Overall, there are three dishwashers, two in the kitchens (one of the two used exclusively for glasses) and one in the café, hand sinks used by personnel are equipped with sensors (Fig 2.14), except for a double compartment sink with double handle faucet used half for hand wash, and half to wash small dishes. Besides, there are two double compartment sinks with double handle faucet (one of them mounted to the wall above the kitchen sink) used for cleaning purposes; two more double compartment sinks with double handle faucet are used to wash vegetables during food preparation. There are, also, two more sinks both equipped with long hose and multi-option spray head, one of them with a double compartment, while the other, single compartment, uses rainwater to clean part of the kitchen (Fig. 2.15). Rainwater is treated through an underground system that uses carbon to filter it. Therefore, rainwater reaches faucet through pump shown in Fig. 2.16, so as to be used for cleaning purposes in the kitchen.

Fig. 2.15: Pre-rinse spray supplied by rainwater

Fig. 2.16: Pump of rainwater treatment system

Also city water is treated through a dedicated system, located in the basement, mainly in order to soften hard water so as to use fewer detergents for the cleaning of the kitchenware. For the same purpose, there is another softener in the kitchen, shown in Fig. 2.17. Besides, before to be used water is filtered in an iron remover shown in Fig. 2.18.

Fig. 2.17: Softner located in the kitchen

Fig. 2.18: Iron remover

In the café, in addition to the dishwasher, there are two double compartment sinks mainly used to wash glasses.

Regarding bathrooms, principally toilets in ladies'toilets are equipped with single flushing, while in gents'toilets there are urinals with sensors. Sinks in the party room have timed-flow pillar tap (with a push down time-flow control and self-closing function) that averagely deliver water for 15 seconds, while sink in the hall and in the café are equipped with sensors.

2.3.5 Fifth Case Study: Restaurant Koevert

Facility type: Restaurant

Location: Kerkhove, Belgium

Potential capacity: Overall 54 seats inside and outside the restaurant

Building Size: 180 m^2 the building and 4800 m^2 the whole lot

Fig. 2.19: Koevert

Koevert is a restaurant just over 20 kilometres from Kortrijk. The structure consists of an interior room, and an outdoor terrace, provided with a garden, mainly used during the summer. In fact, peak customers occurs during hotter periods, in particular from April to September, while customers flow during the week is quite constant. The facility is closed on Saturday and Sunday, but often it holds private parties especially during the weekend. As it can be observed from the graph in Chap.5, water consumption, during observation period, is almost constant, with consumptions variable between 1 m^3 and 3 m^3 per day. The outdoor demand is associated with the presence of the garden, as the irrigation system uses city water, while the indoor demand is related to food preparation, uses for sanitary, cleaning purposes and laundry service. Also in this case, facility has been toured, inventorying equipment and systems for water use.

Regarding the café, located in the lunchroom, it is equipped with a double compartment sink with double handle faucet, and an undercounter dishwasher. It is used mainly to wash glasses, and, for this reason, before to be used, city water is treated in the central system through salt, in order to soften water, using fewer detergents and to obtain more shiny glasses. Touring the kitchen, it could be found a single compartment sink with double handle faucet, used to wash kitchenware. A second single compartment sink with long hose and multi-option spray head is used to clean and a dishwasher. In another wing of the kitchen there is a third sink, double compartment, with double handle faucet, to wash vegetables. Regarding toilettes, there are ladies' toilets equipped with double flushing, and gents' toilets where there are urinals with sensors. Sink have single handle faucet as Fig. 2.20 shows. In the bathroom for staff there are an older sink with double handle faucet, to regulate water flow and water temperature, and a toilet equipped with single flushing. The laundry consists in a wash machine and a dryer necessary for the cleaning of the linen used in the restaurant. Finally, facility is equipped with an ice machine.

Fig. 2.20: Sink located in public restroom

2.4 Summary tables

In the following tables have been summarized equipment features for each business, distinguishing them according to their functions.

Table 2.1: Type of water meter

	Type	**Location**
Chip shop Bossuwé	positive displacement meter	Basement
Cafè Balthazar	positive displacement meter	Basement
Hotel Messeyne	positive displacement meter	Laundry
Restaurant Lindenhof	positive displacement meter	Hall
Restaurant Koevert	positive displacement meter	Kitchen

Table 2.2 Sanitary fixtures and equipment

	Toilets	Urinals	Faucets	Showerheads	Laundry Equipment
Chip shop Bossuwé	2 double flush toilets	-	A hand sink with single handle faucet	-	-
Cafè Balthazar	Double flush toilets	Sensor urinals	Hand sinks with single handle faucet	-	-
Hotel Messeyne	Double flush toilets	Sensor urinals	Sinks with single handle faucets	Single handled tub faucets in the bathtubs; double or sigle rain shower in the showers	Washmachine Brand: Primus, Model SP10; Load capacity: 10 Kg. Dryer Brand: Primus, Model SDH10; Load capacity: 10 Kg
Restaurant Lindenhof	Single flush toilets	Sensor urinals	Timed-flow pillar taps (in the party room) and sensor faucets (in the hall and in the cafè)	-	-
Restaurant Koevert	Double flush toilets and a single flush toilet in the bathroom staff	Sensor urinals	Sinks with single handle faucets and a double handle faucet in the bathroom staff	-	Washmachine Brand: Miele, Model Edition 111 W5873; Load capacity: 8 Kg. Dryer Brand: A&G Electrolux, Model 57830; Load capacity: 7 Kg

Table 2.3 Commercial kitchen equipment

	Sinks				Handsinks	Dishwashers	Ice Machines	Other
	Number of compartment	Type of faucet	Purpose	Water used				
Chip shop Bossuwé	Double	Long hose and multi-option spray head	Washing pots and vegetables	City-water	Whit sensor	-	-	Water Coller Model: Nives Top WG; Water production: 15L/h; Water production continuously: 3L
Cafè Balthazar	Single	Single handle faucet	Washing vegetables	City-water	Whit sensor	Brand: Dishwasher Electrolux Green & Clean Undercounter; Water consumption per cycle: 3L; Working cycles time (sec.): 90/120/240	Brand: Hoshizaki Ice maker;	Water softener
	Single	Long hose and multi-option spray head	Cleaning	City-water				Food warming equipment Oven air-o-steam Electrolux 10 GN 1/1; Wells Stream Furka
	Double	Double handle faucet	Washing pots in the bar	City-water		Brand: Eterna	Brand: Follett	Beer cooler
Hotel Messeyne	Single	Long hose and multi-option spray head	Cleaning	City-water	-	Brand: rhima; Water consumption per cycle: 2,8L; Working cycles time (sec.): 50/180	-	-
	Double	Double handle faucet	Washing pots and vegetables	City-water				

<table>
<tr><td rowspan="7">Restaurant Lindenhof</td><td>Double</td><td>Double handle faucet</td><td>Hand washing and washing small dishes</td><td>City-water</td><td rowspan="7">Whit sensor</td><td rowspan="2">Brand: Jemi, Model GS-85; Water consumption per cycle: 3L; Working cycles time (sec.): 60/120</td><td rowspan="7">-</td><td rowspan="3">Rainwater (used for cleaning purposes) is treated through an underground system using carbon filter</td></tr>
<tr><td>2 Double compartment sinks</td><td>Double handle faucet</td><td>Cleaning</td><td>City-water</td></tr>
<tr><td>2 Double compartment sinks</td><td>Double handle faucet</td><td>Washing vegetables</td><td>City-water</td><td rowspan="2">Brand:Eku, Model: DE-850e Economic-plus; Water consumption per cycle: 2,6L; Working cycles time (sec.): 120</td></tr>
<tr><td>Double</td><td>Long hose and multi-option spray head</td><td>Cleaning</td><td>City-water</td><td rowspan="4">City water is treated in a dedicated system (located in the basement), or in softener (located in the kitchen), in order to soften hard water. After that, it is filtered in an iron remover.</td></tr>
<tr><td>Single</td><td>Long hose and multi-option spray head</td><td>Cleaning</td><td>Rainwater</td><td rowspan="3">Brand: Lamber; Water consumption per cycle: 2,8L; Working cycles time (sec.): 60/120/180</td></tr>
<tr><td>Double</td><td>Double handle faucet</td><td>Washing glasses in the bar</td><td>City-water</td></tr>
<tr><td>Double</td><td>Single handle faucet</td><td>Washing glasses in the bar</td><td>City-water</td></tr>
</table>

Restaurant Koevert	Double	Double handle faucet	Washing glasses in the bar	Treated city-water	-	Brand: Colged, Model Gold GL72; Water consumption per cycle: 3L; Working cycles time (sec.): 60/110/150	-	City water is treated in a central system in order to soften hard water.
	Single	Double handle faucet	Washing pots	City-water				
	Single	Long hose and multi-option spray head	Cleaning	City-water		Brand: Winterhalter, Model GS214; Water consumption per cycle: 2,4L;		
	Double	Double handle faucet	Washing vegetables	City-water				

Chapter 3: Identification of specific projects based on the improvement of water management

In this chapter, that represents the main pillar of the whole work, different measures, aimed to reduce water losses and to optimize water management, have been explained. Particularly, the chapter is divided in three sections, concerning different types of measures. First section regards the importance of monitoring in order to manage water, reduce waste and identify possible leaks. The second section concerns the increasing of water efficiency through more efficient equipment, systems, fixtures and processes, as it can provide significant opportunities for water saving. Sanitary and commercial equipment has been analyzed, reported consumption of different types of fixtures commonly used in hospitality facilities. In the third section, correct standards of behavior, that should be implemented within facilities, have been explained, as the importance of educating employees and occupants encouraging water saving behavior that can produce significant results for water saving.

3.1 Monitoring systems

Monitoring water consumption represents a key step in understanding how water efficiency can be improved, in verifying efficacy of water-saving projects implemented, and, at the same time, it could be helpful to identify leaks, and unnecessary waste. It could be particularly useful for businesses owner, installing more meters, in order to measure specific consumptions, considering building's dimension, types of fixtures and systems and their functions. Besides, a periodic inspection of water using equipment (for example every six months), and maintenance of water systems is necessary, in order to prevent problems and leaks.

One of the most innovative solutions for this purpose is a water consumption monitoring system working through wireless technology. Through this instrument, the user can read his consumption simply connecting to the system. Besides, thanks to this sophisticated technology, when consumption peaks occur, the system is able to analyze them, understanding if they are caused by leaks or simply change of habits. If needed, an alarm signal can be send to the user. [18]

Another particular instrument that could be useful, in order to monitor water used, is device *Water Pebble* (Fig. 3.1). The small circular gadget has to be placed near the plughole of the shower, measuring and memorizing the amount of water used. *Water Pebble* works as a sort of traffic light, through flashing lights green, yellow and red, that permit to signal the quantity of water used during the shower, avoiding waste. Red light warns time is up, when the amount of water required is exceeded. Environmental Protection Agency estimated that showering accounts for nearly 17% of indoor water use, thus, using a shower timer, it is possible to save water, energy and money, shortening shower than 3 minutes and a half. Particularly, manufacturer assessed that, through *Water Pebble*, an average family of four could save up to \$300 (280 €) per year on water and energy costs, including 48 m^3 of water.

Fig. 3.1: Water Pebble
Source: www.greenme.it

3.2 Efficient Fixtures and Equipment

In this paragraph it will be demonstrated the importance of using water-saving technologies, namely products and services that use less water, performing as well as or better than conventional models. Fixtures that save water include low-flow showerheads, faucets aerators, sinks with auto-shutoff mechanisms, water saving dishwashers and washmachines. Reducing water use from fixtures and equipment is perhaps the most immediate method to reduce total potable water use, in fact, with small investments, it can be achieved a significant reduction of the amount of water consumed, and, consequently, an economic profit.

Particularly, important results can be reached acting on sanitary fixtures, laundry and kitchen equipment, as have been discussed in the following paragraph.

3.2.1 Sanitary Fixtures and Equipment

Restroom represents one of the larger uses of water in facilities: the U.S. Environmental Protection Agency (EPA) estimated that, in United States, it accounts for nearly 30% of total water use within restaurants and hotels. [14]

3.2.1.1 Toilets

Toilets can be found nearly in every commercial facility, and in all five businesses examined (as discussed below). The two major types of toilets technologies installed are tank-type toilets (Fig. 3.2) and flushometer-valve toilets (Fig. 3.3). In the first case water falls inside the bowl after pushing the handle that opens a valve inside the tank. Through a water line pressure, air is compressed in the tank, and flushing, it increases water force that moves both water and waste down through sewer pipes. The tank, then, refills until a float shuts off the flow. [16]

Fig. 3.2: Tank-Type Toilet
Source: http://www.digicrawl.com/

Fig. 3.3: Flushometer-Valve Toilet
Source: www.craneplumbing.com/

Conversely, the second type uses a valve that releases a specific volume of water to flush waste into the sanitary sewer system, it is very common in public-use facilities and high use commercial setting. [14]

Before 1980s tank-type toilets consumed approximately 19L to 26.5L per flush , while flush valve toilets use approximately 17L to 19L per flush. Tank-type and flush valve style toilets manufactured between 1980 and the mid-1990s mostly used more than 13L per flush. Today, both are available as dual-flush models that allow to use a standard full flush for solids removal (6L) or a reduced flush for liquid and paper (3L). [16]

It follows that replacing old toilets with low-flow toilets can provide an important opportunities for water saving within facilities, considering, for example, that in a hotel, flush is used, on average, six times per day: four flushes per guest-night, plus two flushes per day during cleaning. [8] It means that the consumption would be at least 78L per guest-night, using an old toilet, compared to 18L using reduced flushes of a more efficient and newer toilet.

Another possibility to increase water efficiency is maintenance: for tank-type toilets it is important checking periodically valve functioning and water level. Besides, to check for leaks, it could be useful putting dye into the tank, after 10 minutes, if it appears in the bowl without flushing, it means there is a leak, and the toilet should be repaired. Regarding flushometer-valve toilets it is necessary, at least annually, check if valve needs to be replaced, simply determining the time of a flush cycle that should be lower than four seconds.

Another way to reduce water consumption is using a cistern-volume-reducing device (Fig. 3.4), putting a weight in the tank (e.g. a bottle), to reduce the filling volume of the tank up to 2.83L. [16]

Fig. 3.4: Cistern-Volume-Reducing Device
Source: www.allianceforwaterefficiency.org/

About replacement, it is advisable to install low-flush toilets, so-called High-Efficiency Toilets (HET) designed to use 4.84L). Consequently, it is possible to calculate water saving simply subtracting to the current water use, the consumption after replacement. A recent study, providing economic data for low-flow fittings, evaluated a payback time of 36 months, considering 70€ as the cost of new fittings, while retrofitting old devices with dual flush, having a cost of 20€, it is possible amortize the expense in 2 months. [8]

In table 3.1 consumptions, of different types of toilet, are summarized, in order to give a more immediate vision.

Table 3.1 Toilets consumption

	Existing Toilets		**Newer Toilets**	
	Pre 1980s	1980s to early 1990s	**Dual Flush**	**HET**
Tank-Type Toilets	19-26,5 L per flush	13 L per flush	6 L per full flush, 3 L per reduced flush	4,84 L per flush
Flush-Valve Toilets	17-19 L per flush	13 L per flush		

3.2.1.2 Urinals

Urinals are widespread in public facilities. The most common type is flushing urinal (Fig. 3.5) that uses different technologies to remove liquid waste. Gravity tank-type urinal (Fig. 3.6) works in the same manner as the tank-type toilet: it uses pressure of water contained in a tank, to remove waste. Siphonic jet urinal, automatically, discharges water stored in the tank, when its level reaches a certain height. The advantages is that this type of urinal does not require user activation. Urinals can, also, be equipped with sensors (Fig. 3.7), that active the flush when user finishes to use the fixture. This type of urinal has no advantages in terms of water efficiency, but only provides health and sanitation benefits, since they are a hands-free option.

Fig. 3.5: Flushing Urinal
Source:www.craneplumbing.com/

Fig. 3.6: Tank-Type Urinal
Source: www.cernlove.org/

Fig. 3.7: Urinal with sensor
Source: www.avsforum.com/

An alternative type is the waterless urinal that saves significant amounts of water and money also because it is more economical, not having a flushing mechanism. Waterless urinal can uses a cartridge for the drain that contains a liquid barrier to prevent the escape of sewer odors (typically it has to be replaced every 7.000 uses), or a self-sailing mechanical waste valve trap.

The typical water consumption for older urinals is from 7.5L to 11.4L, while the newer models, High-Efficiency Urinals, use a flush volume of 1.9L or less. [14], [16]

The same study mentioned above, estimated a payback of 5 months, using waterless urinals through which it is possible to reduce water use to less than 17L per urinal per day, considering a cost of 150€, and an average saving of 375€ per year. [8]

In table 3.2 consumptions, of different types of urinals, have been summarized.

Table 3.2 Urinals consumption

	Existing Urinals	HEU	Waterless Urinals
Consumption	7,5-11,4 L per flush	1,9 L per flush	Cost of cartridges for the drain

3.2.1.3 Faucets

Faucets are very common in facilities, they are used in the restrooms, kitchens and service areas. To increase water efficiency it is possible to install faucets accessories, namely component that can be added or replaced, as flow restrictors, flow regulators, aerators (Fig. 3.8) and laminar flow devices (Fig. 3.9). In particular, aerators, shown in Fig. 3.8, are small devices that adding air to water, reduce the flow from the tap. They located at the end of the faucet and can be used in the kitchen, in the bathroom and also for the showerhead. The devices consist of a mesh screen made of metal or plastic that divides the flow in small streams with air in between, giving the feeling of high pressure with less actual water consumption. In Fig. 3.10 it is shown the difference between a water flow without aerator on the left (irregular stream), and the tap, on the right, equipped with aerator.

Fig. 3.8: Low Flow Aerators
Source: www.niagaracorp.com

Fig. 3.9: Laminar Flow Device
Source: www.crestgood.com

Fig. 3.10: Comparison between water flow without and with aerator
Source: www. eureka4you.com

Faucets can also be equipped with so-called Electric-Eye sensors that deliver water only when user removes hands from the fixture. This type of accessory does not provide particular advantages for water saving, because when the faucet works, the valve is completely open, while, manual control faucet does not turn the tap fully on. However, infrared sensors provide sanitation benefits in public use facilities.

Fig. 3.11: Electronic Sensor faucet
Source: www.sanliv.com/

Another type, mostly used in public-use lavatory, is self-closing faucet (Fig.3.12): it is active by the user and deliver a metered amount of water before shutting-off. [14]

Fig. 3.12: Self-Closing Faucet
Source: www.asia.ru/

Older conventional faucet flow rates can range from more than 11L/minute to 19L/minute [16], but water saving can be achieved by retrofitting existing faucets with aerators or replacing existing faucets.

To improve water efficiency, in private restrooms, retrofitting aerators to existing taps, flow rates lower than 6L/minute can be achieved,[8] on the contrary in public restrooms, it could be possible to install aerators or laminar flow device that deliver less than 2L/minute. [14] To ensure maximum efficiency, it is necessary, periodically, inspect devices, cleaning them to avoid limescale, and eventually replace them, as well as check automatic sensors to ensure they are working properly. [14]

In table 3.3 consumptions, of different types of faucets, have been summarized.

Table 3.3 Faucets consumption

	Existing Faucet	**Retrofitting aerators (private restrooms)**	**Retrofitting aerators (public restrooms)**
Consumption	11-19 L/minute	≤ 6 L/minute	≤ 2 L/minute

3.2.1.4 Showerheads

The Environmental Protection Agency estimated that showering constitutes 17% of residential indoor water use, so, considering businesses water use, this is particularly considerable in hotels facilities. There are several types of showerheads: different shapes, sizes, however, the main types used are fixed showerheads (Fig. 3.13), permanently attached to the wall, handheld showerheads (Fig. 3.14), whit a flexible hose that can be moved by the user and, finally, body spray (Fig.3.15), usually placed on a vertical column on the shower wall.

Fig. 3.13: Fixed Showerhead
Source: www.bathstore.com/

Fig. 3.14: Handheld Showerhead
Source: www.finestshower.com/

Fig. 3.15: Body spray
Source:www.islandbathrooms.co.uk/

Conventional showerheads use from 11.35L/minute to 26.5 L/minute, but nowadays current standards in United States require a maximum consumption of 9.5 L/minute. There are also High-Efficiency Showerheads that reduce water consumption from 20% to 40%, with a consumption of 5.7-7.6L/minute. [14]

In order to improve water efficiency, it is more suitable avoid retrofitting old showerheads with flow restrictors or flow control devices, as newer and more efficient showerheads are not expensive. Thus, best solutions could be replacing older and inefficient showerheads, with lower flow showerheads, variable in price from 20€ to 50€. Considering the price, a study about water management in European hotels, assessed, retrofitting older devices, a payback time of 2-6 months. [8]

In table 3.4 consumptions, of different types of showerheads, have been summarized.

Table 3.4 Showerheads consumption

	Existing Showerheads	Newer Showerheads	High-Efficiency Showerheads
Consumption	11-27 L/minute	≤ 9,5 L/minute	5,7-7,6 L/minute

3.2.2 Laundry Equipment

Laundry operations are particularly significant toward the amount of water used within a facility, besides minimizing water consumption means also reduce energy and chemical use. For small-scale laundry, in commercial, industrial and institutional facilities, water efficiency washmachines have an average water consumption of 7L per kg laundry washed [8], however this is not always achievable for heavily soiled clothes. In order to optimize costs, it is a good practice using devices only with full load (considering a range from smaller 5 kg models to machines with 12 kg load sizes) and use detergents formulated for high efficiency washers. Besides, recycling both wash and rinsing water, it is possible reducing laundry's water demand by about 50 percent. Another water efficiency measures that may be applicable, includes the ozone system. In fact, ozone, injected into the wash, reacts with dirt materials, disinfecting. This system, aside from reducing water consumption by about 10 per cent, allows to decrease water temperature, saving energy, and the amount of detergents by 30 to 90 per cent. However, ozone system can be recommendable only on lightly soiled laundry, but it is not optimal for heavily soiled laundry. [16]

3.2.3 Commercial Kitchen Equipment

As water used in kitchen makes up a conspicuous part of total water use, using efficient equipment and systems can represents an important opportunity in order to reduce water consumption in commercial facilities.

It has been estimated that in restaurants, water used in kitchens accounts for half of total water use, while in other commercial facilities, such as hotels, schools and offices, it constitutes 15 per cent. [14]

The demand mainly consists of food preparation and cleaning purposes, but it can vary depending of dimension of building and their services. However replacing existing service equipment with newer models, can significantly increase the efficiency of the facilities, in terms of water and energy saving.

3.2.3.1 Commercial Ice Machines

Ice machines are very common in facilities such like restaurants and hotels, and are mainly used to make ice. An efficient machine, working without waste water, uses approximately more than 45L of water to produce 45 Kg of ice. However, the amount of water used depends on the quality of water supplied to facilities and on the desired end quality of ice, therefore, the average amount of water required for ice-making process, ranges from 57L to more than 190L per 45 Kg of ice. [14]

In order to optimize and increase machine efficiency it is a good habit to clean it, to avoid limescale formation, keep ice machine's coils clean to guarantee an efficient working, to ensure the appropriate temperature inside the machine.

3.2.3.2 Kitchen Faucets and Pre-Rinse Spray Valve

Intervening on faucets could constitute a key step, as they represent the major source of water in commercial kitchens.

Traditional faucets deliver a flow rate of 9.5L/minute to more than 15 L/minute [16], however the installation of aerators (the same that have been mentioned in subparagraph 3.2.1.3) for kitchen faucets or laminar flow devices, reduces flow rate to approximately 8L/minute. [14] Nevertheless, it is more proper avoid retrofitting inefficient devices with flow control insert to reduce flow rate, as newer and more efficient pre-rinse spray are not expensive.

In order to minimize water waste in commercial facilities, it could be necessary to install temporary shut-off or foot-operated valves, so as to interrupt water flow during activities that do not need water, like soaping. Another efficient option is considering infrared or ultrasonic sensors that activate water flow only in the presence of hands (Fig. 3.16).

Fig. 3.16: Hand sink with sensor
Source: www.prodryers.com/

High-efficiency devices are pre-rinse sprayers (Fig. 3.17) that are very common in commercial kitchens, as they use water under pressure to remove food residue from kitchen utensils before washing them in the dishwasher. [14] While conventional sprayers use between 9.5L/minute to more than 15L/minute, the high-efficiency sprayers use from 6L/minute to 10L/minute. [16]

Fig. 3.17: Pre-rinse sprayer
Source: www.washwareessentials.co.uk/

Besides, in order to optimize the efficiency, it is a good practice inspecting periodically the working of the devices, avoiding limescale formation, that could restrict the flow, and checking for leaks.

3.2.3.3 Dishwashers

Dishwashers are largely used in hospitality facilities and can account for more than one third of the overall water use in a commercial kitchen. [14] Several types of dishwashers are commercially available, however it is important, in order to avoid water waste, choose the most suitable type and size of machine. There are four main classes of commercial dishwashers: undercounter, stationary door type, rack conveyor and flight type. The undercounter (Fig. 3.18) is the smallest one, it is similar to the domestic machines, and it is used in facilities that hold on average 60 people per day. A traditional undercounter dishwasher uses from 3.8 L/rack to 6.8L/rack, while an high efficient model uses 3.8 L per rack. [16]

Fig. 3.18: Undercounter dishwasher
Source: www.he2020.com.au/

The stationary door type (Fig. 3.19) is ideal for larger service facilities, serving up than 150 people per day. It is most widely used for commercial dishwashing machines has one or multiple doors that slide vertically for loading and unloading. The average consumption of a traditional machine is from 4.15 L/rack to 8.3L/rack, while a high efficient model uses 3.6L per rack. In order to improve water efficiency, some stationary door machines have the ability to recycle rinse water to be used again in a wash cycle. [16]

Fig. 3.19: Door-type dishwasher
Source: www.commercialdishwasherlen.blogspot.be/

Conveyor-type (Fig. 3.20) is designed to serve up than 300 people per day, using from 2.65 to 5.3L/rack, the single tank, and 2 to 4.5L/rack the multi tank. However, more efficient machines use respectively 2.6L/rack and 2.2L/rack. [16] Dishes are manually loaded on rack, and it is pulled into the machine using a conveyor. [14]

Fig. 3.20: Conveyor-type dishwasher
Source: www.archiexpo.com/

Finally, flight dishwashers (Fig. 3.21) do not use racks, rather dishes are loaded directly onto the belt through the conveyor that serves as a rack, this type of machine offers high volume washing capability needed in the largest institutional, commercial and industrial facilities. [16]

Fig. 3.21: Flight-type dishwasher
Source: www.restaurantappliancedepot.com/

However, regardless of the type of machine used, some good practices can be put in place both from a behavioral and technical point of view: one of key aspect is educating employees to run dishwasher only with full load, filling maximum capacity, to scrape dishes before loading the dishwasher, and to replace damaged elements and racks. Another efficient option could be installing sensors to allow water flow only when dishes are present, saving water by initiating cleaning cycle less frequently. [14]
Besides, recent models are equipped with electronic functions that allow to select automatically the most appropriate washing program, recording, during the first rinse, the degree of water turbidity.

3.2.3.4 Glassware washers

Glassware washers are very common in facilities offering the bar service. The devices are used to remove chemical particles from glasses and are often supplied with purified water used in final rinse to ensure brilliance. Besides, potable water, used during other stages, can be treated to soften water, avoiding limestone formations.
Also for glassware washers, it is important, in order to decrease water consumption, to run the machines with full load, at maximum capacity. [14]

3.2.4 *Water purification*

Water purification systems are aimed to purify water through physical and chemical means. Several technics can be used, such like carbon filtration or water softening. This first method consists in removing contaminants and impurities, using chemical absorption, while water flows in the carbon filter. Water softening device, on the contrary, removes hardness minerals, as calcium and magnesium.

The most common technic is cation exchange that uses an ion- exchanger devices consisting of positively charged sodium ions attached to a polymer resin. When water containing $Ca^{2+}$and Mg^{2+} passes through the ion- exchanger, they replace the Na^{+} ions, so that softened water (with Na^{+} ions), leaving the ion- exchanger, can be used. [14]

To improve water purification efficiency, it is useful to educate employees and to do maintenance, appraising level of purification required, basing on quality of water incoming.

3.2.5 *Landscaping*

Hospitality facilities consume a significant portion of the overall water use to maintain gardens and landscaping, in fact irrigation represents an important factor. In particular, Eurostat estimated that water use for irrigation purpose in hotels account for 22.5% of the total amount of water used within the facilities. [8] Besides, the U.S. Environmental Protection Agency assessed that, the average landscape water use for commercial and institutional sector, amounts of 7% of total water use for hospitals, 22% for office buildings and up to 30% for schools. [14]

First and more efficient way, to minimise water consumption, is avoid providing irrigation system with potable water, but replacing it with installation of systems supplied by harvested rainwater or grey water. Another important measure that can be implemented is the installation of controlled drip-irrigation systems with electronic controllers and moisture sensors that prevent irrigation cycles when the soil is already wet. In addition, an appropriate garden design and a correct choice of plants can contribute significantly to reduce irrigation needs. Selecting low water using plants and drought resistant plants and grasses in arid areas, and mulching of garden beds to reduce evaporation, are best practices, necessary in order to reduce maintenance costs and make more water-efficient landscaping choices. [4] A climate-appropriate landscaping could be an efficient solution in order to minimize water need.

Particularly, regarding Flemish Region, some of native plants and trees include: alders, oaks, sorbs, ash and purple willow. [17] In table 3.5 pictures of each plants have been reported. Beside, drought-resistant plants, can contribute as well, to reduce the water amount used for irrigation, as they can tolerate dry conditions once they are established. Some examples, resumed in table 3.6, are: Judas tree and pine as trees, lavender and sacred bamboo as plants, grasses as panicum virgatum, and flowers like poppies, sunflowers and marigolds. [18]
Other tips that can be improved are maintaining soil quality, preserving a sufficient quantity of good topsoil to better capture precipitation, minimizing irrigation needs, and maintaining existing plants. Besides, planting additional trees, low water using, can be profitable in order to create shaded areas in landscape design, reducing needs of surrounding plants. [14]
In order to make as efficient as possible the irrigation systems, there are several technologies now available on the market, for instance installing an automatic controller: it automatically will work the sprinklers on the proper day of the week for the correct amount of run time. Beside, this type of device can be equipped with sensors to avoid operation during natural precipitations. Another kind is the so-called smart controller that works using information about soil moisture, rain, wind, slope, plants types and more, using the right amount of water, preventing waste. In addition, more sophisticated technologies include centralized irrigation controllers, used in large sites, for multiple devices at various locations. This type of system utilizes a computer to regulate irrigation for multiple controllers, and to notice alarm situations such as broken pipes or malfunctioning valves. [14]

Table 3.5: Some native plants in Flemish Region (Belgium)

Pictures	Scientific name	Common name
 *Source: www.hogwartsishere.com*	Alnus glutinosa	Alder
 *Source: www.encyclopediaofukraine.com*	Quercus	Oak
 *Source: www.olivamara.it*	Sorbus Domestica	Sorb
 *Source: www.gardeningknowhow.com*	Fraxinus	Ash tree
 *Source: www.commons.wikimedia.org*	Salix Purpurea	Purple willow

Table 3.6: Some example of drought-resistant plants

Pictures	Scientific name	Common name
 *Source: www.globalretreatcentre.org*	Cercis siliquastrum	Judas tree
 *Source: www.deepdale-trees.co.uk*	Pinus	Pine
 *Source: www.onmogul.com*	Lavandula	Lavander
 *Source: www.capegardencentre.co.za*	Nandina domestica	Sacred Bamboo
 *Source: www.imagejuicy.com*	Cortaderia selloana	Pampas grass

 Source: www.pinterest.com	Panicum Virgatum	Switchgrass
 Source: www.giardinaggio.it	Papaver rhoeas	Poppy
 Source: www.bloomiq.com	Helianthus	Sunflowers
 Source: www.commons.wikimedia.org	Calendula officinalis	Marigold

3.3 Good standards of behaviour

In addition to installation of water-efficient fixtures and equipment, a cost-effective way aimed to reduce water consumption and to limit waste, is educating building occupants and employees on using water efficiently. In fact, simple actions as taking shorter showers, running dishwashers and washmachines only with full load, using dual flush toilets, are simple behaviors that can produce significant water savings.

To improve water use, saving-water initiatives and programs have to be adopt and must be explained to visitors and customers, using brochures and promotional materials that encourage water use reductions.

There are several tips that can be follow regarding not only operation and maintenance procedures, but also small changes in users behavior. About kitchen, best practices include washing only full load when using the dishwasher, pre-soaking utensil to reduce the amount of water required for cleaning, filling the sink and turning off the taps while soaping dishes. In particular, researchers at the University of Bonn in Germany [19] compared the efficiency of the hand-washing to dishwasher. They studied the performances of two dishwashers with A/A/A labelling (that means the best in cleaning and drying at a minimum consumption of energy) compared, in the same conditions, to the performances of users coming from 7 different countries, assessing energy, water, time and detergent consumption. Tested people and dishwashers had to wash 12 place settings of dishes, dirtied with seven different kinds of food. At the end of the test the cleaning performance was visually assessed, assigning a score from 0 to 5, where 0 means residues of >200mm² on all items and 5 means no residues left on any item. The same procedure was applied for the two dishwashers. Therefore, evaluating cleaning, it has been shown that cleaning index is approximately the same (3.3). Conversely, about consumption, results showed that it is possible saving working time of at least 1 hour using the dishwasher. Then, evaluating performance it has been estimated that, washing overall 140 pieces, the average water used by tested people of different nationalities, is 103L versus 15L used by a new dishwasher with a normal program, namely one-sixth of the hand-washing consumption. Besides, compared to hand-washing, dishwasher uses only half the energy (2.5 kWh versus 1 kWh) and 30 g of detergent versus, on average, 35 g used by people. [19]

In the bathroom it is convenient installing double flush toilets, low flow faucets, and doing maintenance procedures regularly in order to ensure maximum efficiency, checking for leaks, and inspecting fixtures to avoid scale formation that could restricted flow. Encouraging occupants to reduce water consumption means avoiding faucets from running longer than necessary, turning the tap off during sanitation activities when it is not being used (for instance brushing teeth), taking shorter showers, eventually measuring showering time, avoiding flushing without the need. [14]

Simple behaviors should be implemented also for laundry, first of all, selecting the most efficient washing machines, ensuring they are used with full loads, minimizing the length of the rinse cycle, using high-efficiency detergents. Besides, using cotton-polyester with lower laundry energy demands (compared with pure cotton) [8] and encouraging guests to reuse towels and bed linens in order to reduce laundry volume.

Finally, as it has been explained in subparagraph 3.2.5, best practices regarding irrigation include the selection of drought resistant plants, mulching of garden beds to reduce evaporation, use of rain or grey water for irrigation. [4] Besides, avoiding water during hottest hours when evaporation is high, installation of moisture sensors that prevent irrigation cycles when the soil is already wet, maintaining soil quality.

Best practices, implementable in hospitality facilities, are summarized in table below.

Table 3.7: Best practices implementable in hospitality facilities

Kitchens	Bathrooms	Laundries	Landscaping
✓ Selecting appropriate equipment; ✓ Using full load dishwasher; ✓ Pre-soaking utensil; ✓ Filling the sink before wash dishes; ✓ Turning off the taps while soaping dishes.	✓ Installing water efficient equipment; ✓ Doing periodical maintenance; ✓ Checking for leaks; ✓ Avoiding scale formation; ✓ Turning the tap off when it is not being used; ✓ Taking shorter showers, monitoring time; ✓ Avoiding unnecessary flushing.	✓ Selecting efficient washmachines; ✓ Using machine with full loads; ✓ Minimizing the length of the rinse cycle; ✓ Using high-efficiency detergents; ✓ Using cloth with lower laundry energy demands; ✓ Limiting change of linen.	✓ Selecting appropriate plants; ✓ Mulching of garden beds; ✓ Use of rain or grey water; ✓ Avoiding water during hottest hours; ✓ Installation of efficient system, even equipped with sensors; ✓ Maintaining soil quality.

Chapter 4: Alternative water sources

In this chapter, alternative water sources have been considered. In fact, in addition to measures reported in the previous chapter, such as more efficient technologies and behaviors within hospitality facilities, alternative sources can be used in order to reduce potable water use. In particular, potential water sources include rainwater and treated greywater. In the following chapter, treatment technologies, systems and quality of rainwater and greywater have been explained, focusing on domestic harvesting. Besides, for each of these sources, have been reported examples of facilitates that are using alternative water source in non-potable applications, in order to make water management more efficient and minimizing potable water consumption.

4.1 Potential water sources and their uses

Alternative water sources can supplement or replace the traditional ones. They provide key sources, not only in the dry areas of the world, but nowadays they are being seriously considered in several countries, as these water sources offer the opportunity to offset the use of freshwater in non-potable applications. In particular, potential water sources include rainwater, stormwater, treated greywater, condensate from air conditioning equipment. [14]
Since alternative water sources allow to reduce water supply demand, the total saving, most of the time, can justify costs of treatment technologies. Alternative water quality varies widely, thus, not being healthy for human consumption, most of water resources have limited applications: common uses include landscape irrigation, ornamental ponds and fountains filling and toilet and urinal flushing.
Depending on the standards required, different types of treatment can be implemented, in particular, for high water quality demands, technologically advanced water treatment techniques exist such as ultrafiltration, nanofiltration, hyperfiltration, carbon filtration and ion exchange. [16]
In the following paragraphs, the work will focus on rainwater and greywater reuse, analysing water quality, treatment techniques and potential applications. In addition, real study cases will be reported in order to give an indication of the effective water saving.

4.2 Rainwater reuse: systems, methodology of treatment and purposes

Rainwater harvesting is a system widely implemented, adopted not only in the dry areas of the world, being a useful way to face the global crisis concerning qualitative and quantitative scarcity of water resources.

Rainwater harvesting, in fact, is an efficient way to reduce the use of water for non-potable applications as it can be used in domestic, industrial and agricultural activities such like landscape irrigation, supplying of ornamental ponds and fountains or toilets and urinals flushing. Besides, rainwater harvesting allows to avoid overload of the sewer system and flooding, reducing the amount of runoff. [7]

The quality depends on the flushed surface: water harvested from paved areas highly frequented, as roads or forecourts, is low quality water, as it contains dusts and other pollutants from traffic. On the contrary, water collected from roofs is cleaner and requires minimal treatment. [7]

4.2.1 Rainwater harvesting systems

Focussing on domestic rainwater harvesting, rainwater is collected from roofs, courtyards or low frequented streets.

Depending on precipitation intensity and quantity of water that can be potentially collected, several types of tank can be use, of different size. They can be built underground (Fig. 4.1) or aboveground (Fig. 4.2), and can have different shapes, the most common are cuboid and cylindrical. Regarding materials, smaller storage tanks are usually made of bricks, stabilized soil, rammed earth, while larger containers are built with pottery, ferrocement, or polyethylene. Besides, it is a good practice providing an adequate enclosure to minimize contamination from human, animal or other environmental pollutants. [20]

Fig. 4.1: Underground Rainwater Tank
Source: www.rainharvest.co.za/

Fig. 4.2: Aboveground Rainwater Tank
Source: opstank.wordpress.com

Adopting underground tanks allows to save a significant amount of materials, in fact if soil is suitable to support the expected weight, the walls can be made considerably thinner, as they simply have to avoid seeping into the soil, acting as a waterproof layer. On the other hand, adopting this type of tank, an additional cost, due to the digging of the hole, whose difficulty depends from the nature of the soil, has to be considered, in addition to potential problems that could be caused by leaks in the tank. [21]

In order to avoid economic waste, is advisable choosing appropriately the size of the tank, according to requested needs. It should be underline that convenience of the tank is not strictly proportional to its size. In fact, analyzing water demand satisfied by a tank, compared to its size (Fig. 4.3), it can be seen that the curve assumes an asymptotic trend, namely, after a certain point, increasing tank size, there are not significant variations of demand satisfied. This is due to the fact that a smaller tank will be filled and emptied (cycled) often, while for a larger tank this happens less often. [21]

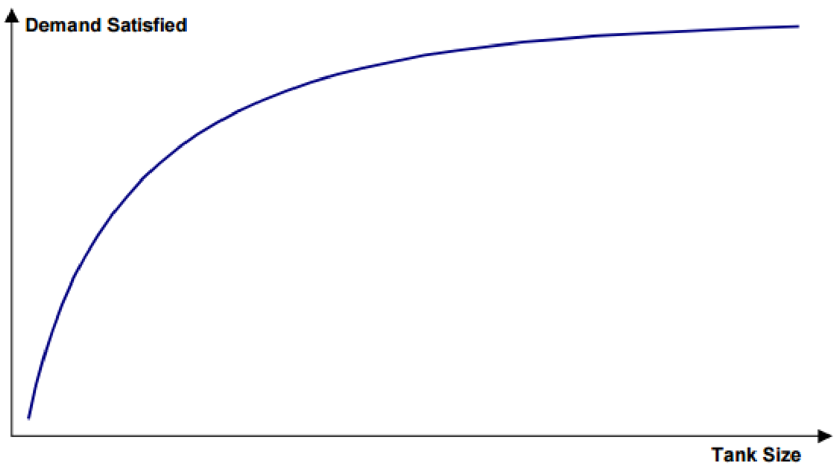

Fig. 4.3: Required Tank size related to demand
Source: [21]

In addition to tank, harvesting surface is a key element in the system, as it affects quality and quantity of rainwater collected. As it has been said in the previous paragraph, generally, roofs are preferable as catchment surface, as water collected is cleaner and requires minimal treatment compared to that collected from other surfaces.

In particular, regarding most suitable types of roof, a Spanish case of study has been reported. In order to encourage alternative water supply, in Spain, researchers, studying different kinds of roof, with different geometry and made of different materials, tried to abstract criteria related to roof slope and roughness. Study aim was estimating the potential volume of rainwater that could be harvested for each roof and assessing the quality of water runoff from them, in order to select the most suitable type of roof. A key parameter, used to evaluate potential water that can be collected in the storage system, is the runoff coefficient RC, dimensionless, that varies according to the type of roof material, considering losses due to leakage and evaporation. RC values has been estimated varying between 0.7 and 0.95, as result of climatic (e.g. intensity of rain) and architectural factors (e.g. slope, roughness). Analyzing four types of roof (made of clay tile, metal sheet, polycarbonate plastic with a slope of 30°, and a flat gravel roof), the quantity assessment showed that, developing a regression model for each of them, the initial abstraction (namely the amount of rainfall that occurs prior to the start of direct runoff) is greater in flat rough roof. On the contrary, potential rainwater harvested from sloping smooth roofs, with RC > 0.90, is approximately 50% higher than flat rough roof, RC = 0.62. [22]

Finally, regarding normative aspect concerning water harvesting, in Flemish Region, the Government has put in place policy measures as a Regional Planning Regulation, in order to supervise and encourage rainwater reuse. In 1999, it decided that a rainwater tank must be included in all new building licenses. Later, in 2005, Flemish Government established that a rainwater tank and pump were obligatory for all newly build and rebuild constructions with a roof surface of at least 75 m², with a minimum capacity of the storage tank of 3000 liter proportionally to the roof surface. Besides, policy implemented by Flemish Government provides subsidies for the installation of a rainwater harvesting system also when the installation is not obliged. [23]

Contrarily, in Italy, there is not a specific national legislation regulating harvesting of rainwater in reservoirs and tanks for industrial or civil use, in spite of the realization of these artefacts is regulated by lows concerning building in earthquake zones, dams and dykes and other special laws (subpar. 4, art. 96, Leg. D. 3rd April 2006, n. 152). [24]

4.2.2 Rainwater quality

Rainwater quality is closely related to the type of surface once it is collected, as the catchment surfaces represent a source of heavy metals and organic substances. Generally, water collected from roofs is cleaner that water collected from roads that may be polluted by heavy metals originating from brakes and tires, and by organic compounds like polycyclic aromatic hydrocarbons (PAH) and aliphatic hydrocarbons from incomplete combustion processes. [20]

In general, several kinds of chemical contaminants can be found into rainwater, as heavy metals, microorganisms, fecal indicator bacteria and potential pathogenic bacteria and protozoa. [25]

Regarding roofs, it has been evaluated that water collected from roof made of tiles, slates and aluminium is low polluted, on the contrary, zinc and copper roofs or else roofs with metallic paint, are not recommended as water harvested would contain a significant amount of heavy metal. In this regard, researchers at the University Pertanian Malaysia compared rainwater quality collected from a tile and a galvanized-iron type roof. They estimated that concentration of pollutants is higher at the beginning and decreases during the precipitation. Samples collected from the two types of roof, show that parameters decrease in concentration after first liter of rainwater collected, except for lead and zinc. In particular, the average lead concentration of 200 µg/L resulted consistently high in both cases compared to limit value of 50 µg/L, for drinking water, reported by WHO (Water Health Organization) in Drinking Water Quality Guidelines. Besides, zinc concentrations in the run-off from the galvanized-iron roof, with an average value of 423 µg/L within first five samples, was about five times higher compared to the tile roof. However, as the maximum concentration recorded was 1748 µg/L, values are lower than limit of 5000 µg/L fixed by WHO for drinking water. The maximum pH value of rainwater collected from galvanized-iron and tile roof was respectively 6.6 and 6.9, well comparable to the optimal value established from WHO ranging between 6.5 and 8.5 for drinking water. Besides, they found that faecal coliform (originated from faecal pollution by birds, mammals and reptiles that have access to harvesting area) and total coliform counts ranged from 8–13 (tile roof) and 4–8 (iron roof) to 41–75 (tile roof) and 25–63 (iron roof) colonies per 100 ml, respectively. However, researchers evaluated that rainfall intensity and the number of dry days preceding a rainfall event are key factors that can significantly affects the quality of run-off water. [26]

Another study, conducted in Texas, highlights the influence of roofing material on the quality of rainwater harvested from six different types of roofs: galvanized metal, cedar shake, asphalt shingle, two types of treated woods and green. In particular, the latter, is increasingly being installed for its stormwater retention characteristics. During the study, pilot-scale roofs and full-scale roofs were used. In the first case, they were built in 2009, and made of asphalt fiberglass shingle, Galvalume or concrete tile, while the alternative types, built in 2007, were an unfertilized green and cool roofs. The full-scale residential roofs were a Galvalume roof (12 years old) and two asphalt fiberglass shingle roofs (5 years old) with different inclination. Results show that rainwater harvested from roofs analysed, requires treatment, according to United States Environmental Protection Agency primary and secondary drinking water standards or non-potable water reuse guidelines. For first flush, at least, diversion, filtration and disinfection are necessary. Generally, metal roofs, concrete tile and cool roofs, are preferable as harvesting surface, also because water collected from metal roof examined, contained a low concentration of faecal indicator bacteria than other materials. Besides, water harvested from green roof showed high concentration of dissolved organic carbon, in addition, the concentration of some metals, like arsenic, makes necessary further examinations if rainwater is being considered for domestic use. [25]

4.2.3 Rainwater treatments

First action that can be implemented in order to improve rainwater quality is adopting the first flush water diverters (Fig. 4.4): it is a device, easily to install, required to remove the first flush of a rain event that may contain contaminants from the roof, avoiding to let they enter in the tank. [20] Practically, polluted water is diverted water into the device, instead of flowing towards the tank. When the water level in the diverter chamber rises, the ball floats, and once the chamber is full, the ball rests inside the diverter chamber preventing any further water entering the diverter. The subsequent flow of water is then automatically directed to the tank. [27]

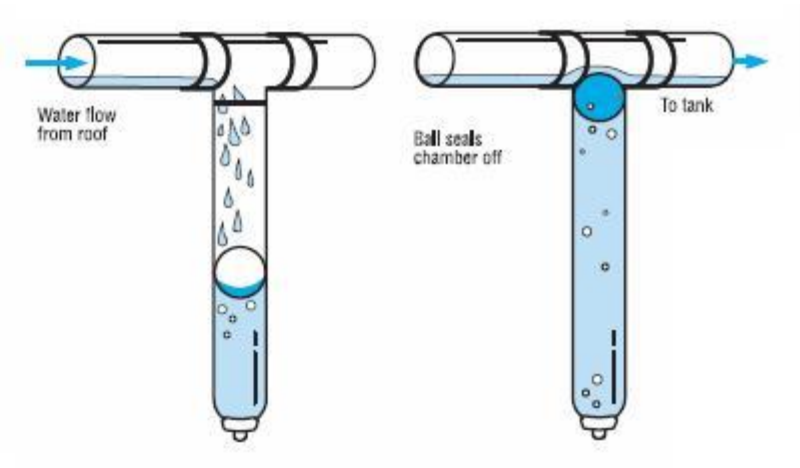

Fig. 4.4: First Flush Water Diverter Working
Source: www.basixcertificatecentre.com.au

In addition, in order to disinfect rainwater, the most common method is chlorination, through with it is implemented the deactivation of most microorganisms. This method is relatively cheap, but it has to be applied after removing harvested rainwater from the tank, because chlorine may react with organic matter which settled to the bottom of the tanks. However, it has to be considered that some parasitic species cannot be removed through this technique, especially using low quantity of chlorine. [20]

Another disinfection method, widely used for treating rainwater, is slow sand filtration: it is a biological treatment implemented through a filter made of sand layers coarsest on the top and finest at the base. The filter remains efficient for many weeks, but in order to be effective, the system needs a constant flow of water through the filter. [20]

Pasteurization by solar technology represents an alternative low cost treatment method for harvested rainwater that can be achieved by combining UV-A radiation with heat. This technique, through sun energy, can be efficient, using a water temperature of at least 50°C. Pasteurization by solar technology implemented through plastic bottles or bags (batch) or continuous flow (SODIS) reactors. First technology is sufficient for small households, on the contrary the solar water disinfection through continuous flow reactors, can produce 100L of disinfected water per square meter of solar collector per day. However, solar technology is useful only when the concentration of suspended solids is less than 10 mg/L. [20]

In general, a rainwater harvesting system is made up of three elements: a collection area (it is usually the roof of the building), a conveyance system, and a storage tank. As it has been said in previous sub-paragraph, the quality of harvesting depends on the type of roof, generally tiled roof are preferable. The conveyance system consists of pipes that direct water collected from the roof to the tank, pipes size has to be appropriate in order to improve the efficiency of the system. The size of the gutters is related to the area of the roof and the rainfall amount and usually ranges between 20–50 cm diameter. [28]

4.2.4 Examples of rainwater reuse

In airports a large amount of water is used every day, due to the large circulation of people. For this reason, in last decades, a growing interest, in more efficient water management, is developing. Between most relevant actions carried out in airports, rainwater reuse seems to be one of the most convenient, not only for economic advantages, but also considering social and environmental benefits. Beside, in airports there are wide impervious surfaces, also thanks to the impermeabilization of the soil that represents potential collection areas.
Several airports in Europe and all over the world, implemented rainwater harvesting systems, in order to reduce water consumption and to exploit this important source for non-potable water use within the infrastructures.
For instance, Orly Airport in Paris, since 1996, has been equipped with rainwater treatment system, that supplies the air conditioning system and heating network, and a small part is used for fire control, saving 70.000 m^3 of potable water per year. About 4 million m^3 of water are treated every year by the system, producing about 50–100 t of sludge. Besides, some buildings at Brussel International Airport are fitted with six rainwater collectors of 10 m^3. Rainwater harvested is used for flushing toilets and cleaning purposes. Rainwater system at Heathrow Airport in London is the biggest in Europe and can use 85% of rainfall, using it together with borehole water, to provide 70% of non-potable water needs in Terminal 5. Finally, at Galeao Airport, in Rio de Janeiro, 1500 m^3 of rainwater are collected monthly, and, combined with treated sewage effluent, provide cooling systems. [29] Regarding potential savings reusing rainwater within residential sector, researchers from University of Santa Catarina in Brazil, estimated that a significant amount of potable water can be saved, using alternative sources as rainwater collecting from buildings roofs.
They studied 62 cities in the state of Santa Catarina, analyzing the average potable water demand, that accounted for 118 liters per capita per day, and the monthly volume of rainwater that could be harvested, considering an average rainfall of about 1700 mm per year. Results show that average potable water savings represent 69% of the amount of potable water currently used, ranging from 34% to 92% depending on the potable water demand. [30]

4.2.5 Potential water saving

Evaluating economic costs and advantages, reusing collected rainwater, it is important considering also social and environmental benefits. For this reason, it is difficult to measure the real economic value of water reuse. [29]

However, to evaluate the amount of rainwater that can be collected for each rain event, it is a good practice to assume that 0.99 L of water can be harvested per square meter of collection surface per millimetre of rainfall.

Besides, most rainwater collection system installers use to assume a capture efficiency of 80%, considering that 20% is lost through evaporation or other means. Thus, the equation to calculate potential rainwater harvested, is:

$$RWH = A \cdot Ap \cdot Rc \cdot E$$ [14]

Where:

- *RWH* is potential rainwater harvested per year;
- *A* is roof area expressed in square meter;
- *Ap* is the annual precipitation expressed in square mm per year;
- *Rc* is rainfall captured per roof area (0.99L per square meter per millimetre of rain);
- *E* is collection efficiency, namely 80%.

To be clearer, considering a roof area of 100 m^2, and an average annual precipitation of 847 mm per year recorded in Belgium, [31] approximately 67.000L of water can be collected.

Tank size, of course, depends on the potential volume of rainwater that could be collected, in particular, the volume can be calculated as:

$$V = \frac{RWH \cdot Dp}{365}$$ [32]

Where:

- *V* is the volume of the tank estimated;
- *RWH* is potential rainwater harvested;
- *Dp* is the annual dry period, namely amount of weeks or days during which the absence of precipitation can verify;
- *365* are days in a year.

Dp is calculated as: [33]

$$Dp = \frac{365 - F}{12} = \frac{365 - 136}{12} = 19\ day/month$$

Where:

- *365* are the days in which tank is used;
- *F* is frequency of rain, namely rainy days during utilization period. In Belgium rainfall days are, in average, 136 per year [34];
- *12* are the months in which tank is used.

Referring to previous example, the necessary volume of storage tank can be estimate as:

$$V = \frac{67000 \cdot 19}{365} = 3854\ L = 3.487\ m^3$$

Beside, the same size of the tank can be estimated from the following graph [35] (Fig.4.5). It reports the trend of the tank volume per 100 m^2 of harvesting surface, as a function of the rainwater use per day per 100 m^2 of harvesting surface, considering different curves representing percentage of time during which tank is empty and tap water is used.
In particular, considering an average rainwater use of 150 L/day and a harvesting surface of 100 m^2, referring to the period of 19 days that represents 5.21% of the year, namely percentage of time during which tank is empty, it is possible assessing a volume of about 3-5 m^3.

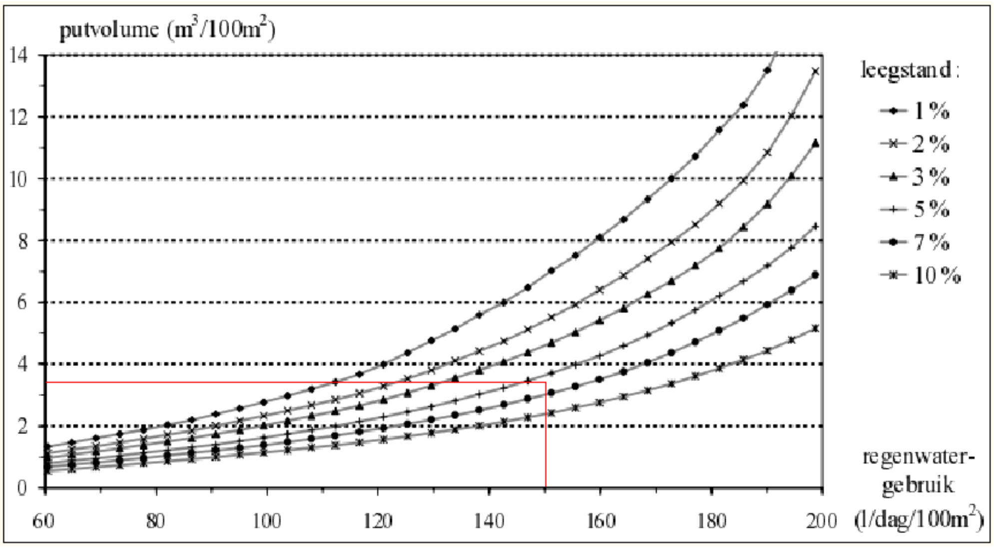

Fig. 4.5: Relationship between tank size per 100 m^2 of harvesting surface and rainwater used per day
Source: [35]

On the other hand, the investment costs of the system varies significantly and it depends upon size of storage tank required, type, quantity of materials used. In particular, an underground storage tank system is generally more expensive than an aboveground system for the same storage tank size. A study reports that in Ireland in 2009, the general costs for the systems ranged from €1.500 to €4.000 with storage tank sizes between 1500 L and 10.000 L. Besides, researchers estimated a payback period for a system between 7 and 20 years in Ireland. However, with increasing water and energy costs, the payback period could decrease. [36]

4.3 Greywater reuse: systems, methodology of treatment and purposes

Greywater is the water collected separately from sewage flow that originates from clothes washers, bathtubs, showers and sinks, but does not include wastewater from kitchen sinks, dishwashers, or toilets come in contact with waste. Besides, it has been estimated that dishes, shower, sink, and laundry greywater constitutes 50-80% of residential wastewater. [37]
As rainwater, also greywater can represents an important alternative source to supply non-potable in site applications as irrigation systems, and toilets and urinals flushing, reducing significantly the amount of potable water used.
Greywater distinguishes from blackwater as the latter is highly polluted by organic matters and pathogens. On the contrary greywater may contain varying concentrations of organisms that are washed off during bathing and from clothes during laundering, and may also contain oils, grease, fats, hair, lint, soaps, fabric softeners cleansers, and other chemicals. [38]

4.3.1 Greywater quality

Greywater quality is highly variable. However, the analysis of the grey water characteristics indicates that the kitchen greywater and the laundry greywater contain higher level of both organics and physical pollutants, compared to the bathroom and the mixed greywater. Besides, analysis of the greywater quality, also show that bathroom and laundry greywater are less contaminated by the microorganisms, compared to the other greywater streams. In particular, likewise to the bathroom greywater, the laundry greywater and the mixed greywater are lacking in nitrogen. In some cases, the laundry greywater and the mixed greywater are low in phosphors due to the use of phosphors free detergent. [39]

Kitchen greywater contributes the highest levels of organic substance, suspended solids, turbidity and nitrogen. Besides, due to the presence of the large amount of easily biodegradable organic substances, kitchen grey water is more contaminated by the thermal tolerant coliforms than other grey water streams. [39]

Main characteristics of greywater by different categories are summarized in Fig. 4.6.

	Bathroom	Laundry	Kitchen	Mixed
pH (−)	6.4–8.1	7.1–10	5.9–7.4	6.3–8.1,
TSS (mg/l)	7–505	68 – 465	134–1300	25–183
Turbidity (NTU)	44–375	50 – 444	298.0	29–375
COD (mg/l)	100–633	231 – 2950	26–2050	100–700
BOD (mg/l)	50–300	48 – 472	536–1460	47–466
TN (mg/l)	3.6–19.4	1.1 – 40.3	11.4–74	1.7–34.3
TP (mg/l)	0.11– >48.8	ND – >171	2.9– >74	0.11–22.8
Total coliforms (CFU/100 ml)	$10–2.4\times10^{7}$	$200.5–7\times10^{5}$	$>2.4\times10^{8}$	$56–8.03\times10^{7}$
Faecal coliforms (CFU/ 100 ml)	$0–3.4\times10^{5}$	$50–1.4\times10^{3}$	–	$0.1–1.5\times10^{8}$

Fig. 4.6: Greywater characteristics
Source: [39]

It is important using greywater collected within 24 hours, as it can foster bacteria and pathogens. If greywater is used for irrigation needs, it is necessary to avoid using it directly on plants intended for human consumption, but it is a good practice applied it below soil surface. [14]

4.3.2 Greywater treatments

It is important to underline that greywater treatments vary from simple processes that consist of removing suspended solids from the water, to more advanced ones, according to requirements required by different uses. There are several types of treatments, including physical, chemical, and biological systems, generally they are preceded by a solid-liquid separation step as pre-treatment and followed by a disinfection step as post treatment. [39]

In order to properly reduce organics, nutrients and surfactants, physical processes alone are not sufficient. Chemical treatments can efficiently remove organic materials, surfactants and suspended solids in low strength greywater. Finally, the most economical solution is the combination of aerobic biological processes with physical filtration and disinfection. [29]

However, basic treatments are sufficient for subsurface irrigation applications.

4.3.3 Examples of greywater reuse

Due to the large amount of water used in airport, there are several examples that improved water management efficiency, through recycling of greywater. In particular, Hong Kong Airport is equipped with a treatment system, through with water collected from aircraft catering facilities, terminal building kitchens and water runoff from aircraft washing activities, is treated and used for irrigation applications. The treatment system uses three Membrane Biological Reactor (MBR) tanks with a total of 8,000 membrane panels to make greywater suitable for irrigation. [40] At Narita Airport, in Japan, greywater, derived from kitchen wastewater of terminal restaurants, is recycled for flushing in terminal toilets. It is treated at the Kitchen Wastewater Treatment Facilities where impurities are removed and biodegraded. Afterwards, water is taken to the Grey Water Production Facilities where it is disinfected and purified through membrane separation and activated carbon absorption, allowing it to be reused as greywater. [41] Finally, at Fiumicino Airport, water originated from terminal restaurants and water used for preparing the food served in the aircraft, is treated together with domestic sewage, using an active sludge biological plant. [29] The system treats wastewaters originated from the toilet and canteen facilities, and is capable of treating up to 12,000 m^3 of waste per day and achieving a reduction performance of the polluting agents exceeding 80%.

Another example of greywater reuse was implemented in a hotel in Mallorca Island (Spain), where treated greywater was used for toilet flushing. Technology used by the system is based on filtration, sedimentation and disinfection treatments using hypochlorite as the disinfecting agent. Through this system 5.2 m^3 per day of wastewater, coming from bathtubs and hand-washing basins, was reused, representing 23 % of the total water consumption of the hotel. It was estimated that whole cost, consisting of construction of the system, amounts for 17000 €, while maintenance costs account for 0.75 €/m^3. From these data a saving of 1.09 €/m^3 was evaluated with a 14-year payback. [13]

Results

Chapter 5: Water saving and economic benefits

In this chapter for each of the five facilities analyzed, water consumption and potential water savings have been assessed. First of all, graphs have been compiled, representing the trend of water consumption for each of them, extrapolated in an observation period, lasting three months, from Monday 21st September 2015 to Sunday 20th December 2015. Study of water consumption, in the five facilities analyzed, shows that there is a great variation between them, in spite of they are located in the same country and in neighboring areas. Certainly, this is due to the types of services offered and to different sizes of buildings, as well as to the equipment and systems using water. Thus, water using fixtures, equipment and systems currently used, explained in Chap. 2, have been evaluated and their consumptions have been compared with more efficient one, exposed in Chap. 3.
Moreover, different measures, aimed to reduce water losses, have been taken into consideration, as well as use of alternative sources in non-potable applications, in order to reduce potable water use. In particular, focusing the attention on rainwater reuse, possible utilizations have been considered, calculating potential quantity that can be collected, basing on different types of harvesting surface available for each facility, also comparing overall costs with benefits arising from rainwater reuse.
For each of these measured, aimed to optimize water management, related savings have been calculated, from the point of view of saving water as well as in monetary terms, considering the average water rates in (West-)Flanders.

5.1 Drinking water supply and water price in Flemish Region

In Flanders, the supply of drinking water is a municipal task, in fact municipalities are associated into drinking water companies. There are eight water distribution companies formed out of an association of municipalities; six municipalities distribute drinking water on their own and there is one regional Flemish drinking water company. [42] Beside, from 1997 to 2015 the Flemish Region established that, to every inhabitant, minimal supply had to be ensured, consisting on 15 m³ of free water per person per year, as recommended by the World Health Organization (WHO), regardless of the number of inhabitants per household. In this way, every customer had the right to be connected to a drinking water distribution network, in order to guarantee an adequate standard of living. [42], [43] In Flemish Region, the price of water is made up of three tariffs: the first one is a basic fee due to fixed costs of connection, independent from the amount of water used, a second part of the price regards a municipal contribution, and finally the third is a variable cost depending on the consumption. In fact, the region has implemented a progressive water-pricing mechanism, so that the third part of the tariff varies according to the amount of water used, and it is calculated considering different block of water consumption established by the distribution company and regional authorities. [43] In addition, lately, also a cost due to wastewater treatment is accounted in overall price. The graph below (Fig. 5.1) refers to the tariffs constituting the whole price of water per cubic meter in 2014 for different Belgian companies, considering the average household consumption of 84 m^3 per year.

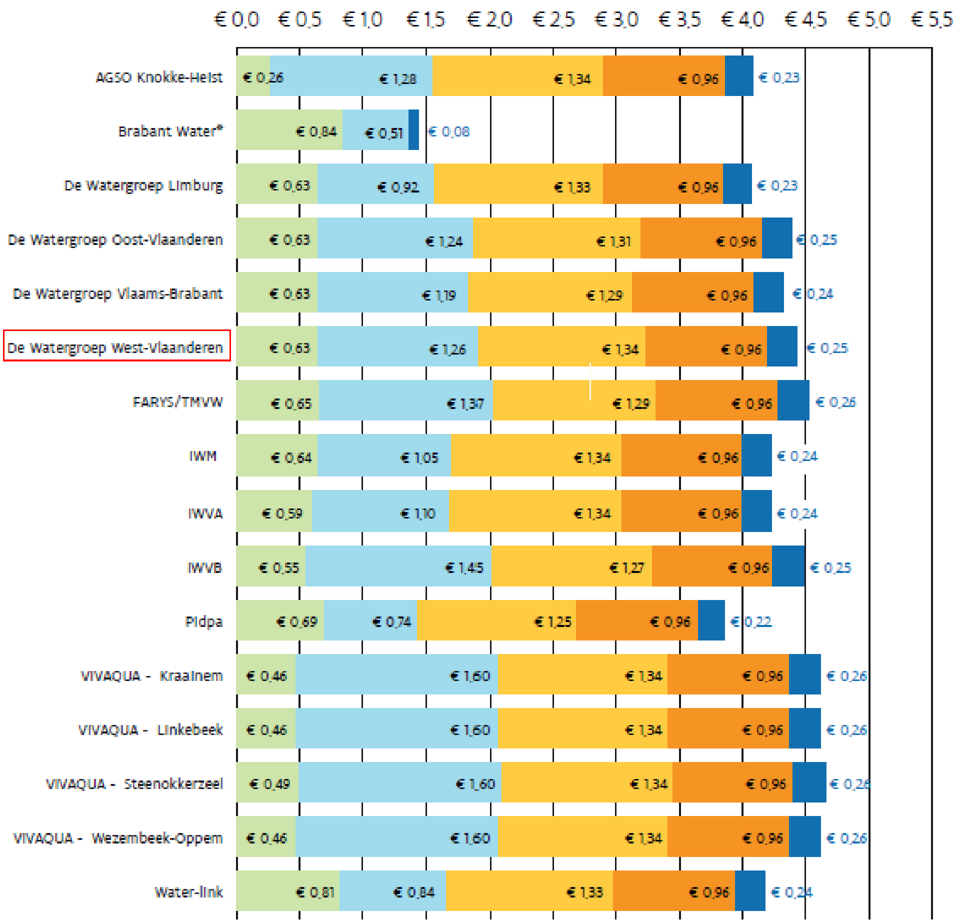

Fig. 5.1: Water tariffs per m³ for an average family in Belgium
Source: [44]

As it can be seen, considering the West Flemish Region, the price of water supplied account for 4.44 € per cubic meter, so, in next calculations, an average price of 4.50 € will be considered. In particular, the graph shows in green the fixed tax, highly variable, ranging from 0.26 € of AGSO Knokke-Heist, to 0.84 € of Brabant Water, while the variable tax is indicated in light blue. Moreover, the municipal contribution and an supra-municipal contribution, shown respectively in yellow and orange, do not present great variations, as the first ranges between 1.25 and 1.34 €, with an average value of 1.31€, while the second is fixed on 0.96 € for all the companies. Finally, the part concerning the VAT 6%, is shown in blue. [44]

In Italy, water service tariffs are highly variable, because there are several factors that influences them, varying between different Italian zones, as types of treatments used, the distance from sources, cost related to the sewer, and sewage treatment plants. The highest price of water is registered in central Italy, with an average water cost of 2.12 € per cubic meter, followed by North-East regions (1.69 € per m^3), South regions, Sicily and Sardinia (1.59 € per m^3), and finally North-West regions with the lowest price of 1.28 € per m^3. Consequently, the average cost of water in Italy, among the lowest in Europe, is 1.62 € per m^3, where fixed tax represents about 7%, water service 53%, sewerage service account for 13%, treatments for 27%.[45]

In Basilicata Region, considering a domestic use and an average consumption of 100 m^3 per year, the whole price is made up of a fixed fee of 0.23 €, a variable fee of 0.56 €, sewerage service of 0.18 €, treatment contribution of 0.38 €, so it amounts to 1.35 € per m^3. Table 5.1 shows the different prices applied in Basilicata by Acquedotto Lucano, implementing a progressive water-pricing mechanism, referred to 2014. [46]

Table *5.1*: Water tariffs per m3 in Basilicata Region
Source: [46]

Utenze Domestiche	
Fasce	**2014**
0 - 100 mc/a	€ 0,56
101 - 150 mc/a	€ 0,71
151 - 250 mc/a	€ 1,16
oltre 250 mc/a	€ 1,86
Fogna	€ 0,18
Depurazione	€ 0,38
Quota fissa	€ 23,00

5.2 Potential water-saving for cases study

In this paragraph all five cases study will be analysed: each business will be studied in order to understand how they can significantly reduce water use. In particular, several potential water-saving opportunities, widely commented in previous chapters, will be taken into account, identifying possible implementations within facilities.

The sections concerning each facility consist in a first part where consumption data are analyzed, these information have been made available through a daily monitoring of water meter for three months, namely 13 weeks (from 21st September 2015 to 20th December 2015), thanks to which average consumption are known and fluctuations in water use have been registered.

A second part concerns identification of water-saving opportunities, through eventual replacement of current equipment with new and more efficient ones, implementation of simple behavioral practices aimed to reduce wastes. Thus, potential saving in monetary terms will be calculated.

In the third part, alternative water sources, in particular rainwater, are considered in non-potable applications, in order to make water management more efficient and minimizing potable water consumption. Also in the third part, an economic evaluation will be made, estimating potential saving and payback period, after having calculated potential quantity that can be collected, basing on different types of harvesting surface available for each facility.

Finally, for each case of study, the overall potential saving will be summarized in a table in order to clarify the evaluations.

5.2.1 First Case Study: Bossuwé

5.2.1.1 Consumption analysis

The chip shop is located in Wevelgem, holds 50 seats, and counts a surface of 120 m^2. Peak customers occurs at lunchtime (from 11:00 to 13:00) during the day, between Friday and Saturday during the week, instead the peak during the year occurs during school holidays and summer period (June, July and August). The business is closed on Sunday, and it is open every day from 11:00 to 14:00 and in the afternoon from 17:30 to 22:00.

More detailed information about Bossuwé are provided in Chap.2 §2.3.1.

In Bossuwé, the indoor demand consists of uses for sanitary, food preparation and cleaning purposes. Data available regard 8 weeks out of 13 (total observation period), namely 41 observations. Bringing in the graph (Fig. 5.2) the trend of daily consumption in function of time, from the analysis, it can be seen that the higher values have been registered during the weekend, namely on Saturday, referred to Friday evening, and on Monday, referred to Saturday, as Sunday is the closing day.

The average water consumption recorded is 0.619 m^3 per day, namely 619 L per day, with a maximum consumption of 1.749 m^3 registered on Saturday 26th of September, and a minimum value of 0.322 m^3on Thursday 22nd of October.

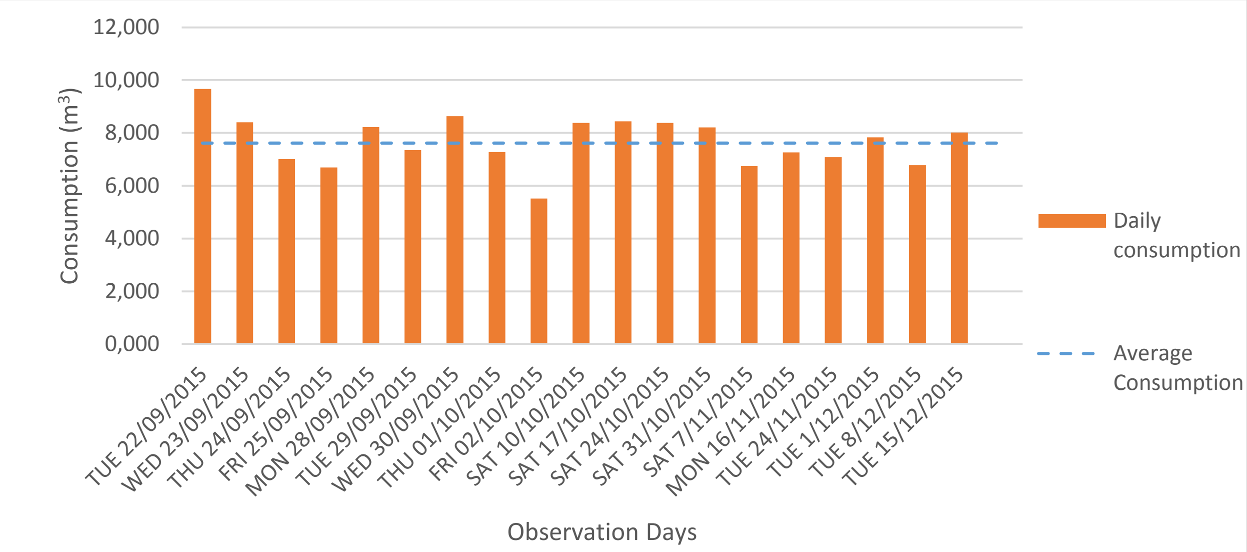

Fig. *5.2*: Daily Water Consumption in Bossuwé

Moreover, the number on the water meter after Christmas holidays has been recorded, in order to analyse possible changes in water use. In this case, the facilities was closed on 25th, 26th and 27th December, and 1st, 2nd, 3rd January, therefore evaluating water consumption between 19th December (last day of observation) and 5th January, considering only opening days, the average daily water consumption was 0.77 m^3, namely 0.151 m^3 more than the average daily water consumption during normal days, as it was expected due to the increased flow of customers during holidays.

5.2.1.2 Evaluation of current equipment and possible replacements

Analysing current equipment situation and evaluating possible replacement, it has to be observed that Bossuwé is opened since February 2014, so current fixtures can be considered almost new, besides, being building dimension limited, cannot be found a lot of saving opportunities considering replacement.

Regarding public restrooms, current toilets (one for gents and the other one for ladies) equipped with double flushing, can be considered an efficient solution in order to improve water management, using 6 L per full flush, 3 L per reduced flush. Moreover, sink faucet also, accounts for a significant percentage of the water used on average. In addition, to increase water efficiency, it is advisable equipping the existing single handle faucet with faucets aerator that, adding air to water, reduces the flow from the tap. The device is available at common ratings of 1.9, 2.8, and 3.8 L/minute [16] and it can be easily found on the market at the average price of 4.50 €, ranging generally from 1 to 10 €. Considering an average existing flow rate of 8.3 L/minute, it is clear that, thanks to the remarkable cut to water used by tap, and to low price, the device yields a payback within a few months. Further information are shown in table 5.2.

Concerning kitchen equipment, the pre-rinse spray, equipping the double compartment sink, represents a high-efficiency device, using less water, in fact, while conventional sprayers use between 9.5 and 15 L of water per minute, the high-efficiency sprayers use from 6 to 10 L per minute. [16] However, in order to optimize the efficiency, it is a good practice inspecting periodically the working of the devices, avoiding limescale formation, that could restrict the flow, and checking for leaks. In the kitchen, there is also a small hand sink with sensor that can be considered an efficient option as it activates water flow only in the presence of hands, using on average 6 L/minute.

As it is anticipated, equipment used in kitchen and restroom are all-in-all considered sufficiently efficient in order to minimize water consumption, as they date back only to one year ago, so there is no need of replacements, or significant changes.

5.2.1.3 Implementation of correct standards of behaviour

In addition to installation of water-efficient fixtures and equipment, a cost-effective way aimed to reduce water consumption and to limit waste, is the implementation of correct standards of behavior. In Bossuwé, most important change that could be implemented regards washing dishes: as it has been said in Chap.2, in the kitchen, there is no dishwasher. Interviewing employees, it was revieled that washing is carried out at least three times per day, during the morning, afternoon and evening, spending overall, on average, three or four hours per day. In addition, during the weekend there is an additional employee, attendant to wash dishes only in the afternoon.

A commercial dishwasher, as a high efficient model of undercounter, ideal for facilities serving on average 60 people per day, uses 3.8L per rack, namely per washing, considering a capacity similar to residential dishwashers.

Therefore, considering 4.50€ as the price of a cubic meter, considering at least 8 cycles, namely washing of 8 full racks per day (on average 1 per hour) the total consumption would be little bit more than 0.13€. This value is calculated as:

$$Consumption = \left(\frac{8\, racks \cdot 3.8 \frac{L}{rack}}{1000\, L} \right) \cdot 4.50€ = 0.136€$$

Conversely, current hand-washing is more expansive in monetary terms, as well as time, in fact, in spite of considering using an efficiency sprayer, as it is said in the third Chapter, the minimum consumption is 6L per minute. Asking to the employees if they use to fill the sink to soap dishes, they affirmed that they do it sometimes, but they use also to wash with running water. Therefore, considering that, on average, employees spend 4 hours per day washing dishes, and estimating that at least for 50 minutes they use running water, water consumption accounts for 300 L, namely 1.35€.

$$Consumption = \left(\frac{50\, min \cdot 6 \frac{L}{min}}{1000\, L} \right) \cdot 4.50€ = \left(\frac{300\, L}{1000\, L} \right) \cdot 4.50€ = 1.35€$$

In conclusion, considering an average price of 1100€ [47], to calculate the simple payback associated with adopting a high efficient dishwasher, it has been estimated that, being the daily saving 1.22€, the payback period accounts for 2 years and half. Moreover, it could decrease drastically, considering that the use of the machine permits to avoid recruiting the additional employee during weekends.

Concerning other correct standards of behavior in the bathroom and kitchen it is convenient doing maintenance procedures regularly in order to ensure maximum efficiency, checking for leaks, and inspecting fixtures to avoid scale formation that could restricted flow.

Finally, encouraging occupants and employees to reduce water consumption means avoiding faucets from running longer than necessary, turning the tap off during sanitation activities, as soaping hands, when it is not being used. To improve water use, saving-water initiatives and programs have to be adopt and must be explained to visitors and customers, using brochures and promotional materials that encourage water use reductions.

5.2.1.4 Potential Rainwater reuse

Rainwater harvesting could represent an efficient way to reduce the use of water for non-potable applications in Bossuwé, as it can be used in domestic activities such like toilets flushing or cleaning purposes. It should be stated that the building has no green areas, therefore, use of rainwater for landscape irrigation is not expected.

For the case study under consideration, as the building is located in a housing area, due to the presence of underground services, it is preferable adopting an aboveground rainwater tank. In order to avoid economic waste, it is advisable choosing appropriately the size of the tank, according to requested needs, as the price varies in function of the volume. As it has been said in the previous chapter, generally, roofs are preferable as catchment surface, as water collected is cleaner. Besides, in order to improve rainwater quality, a first flush water diverters should be adopt, to remove the first flush of a rain event that may contain contaminants from the roof, avoiding to let they enter in the tank.

In order to evaluate the amount of rainwater that can be collected for each rain event, it is a good practice to assume that 0.99 L of water can be harvested per square meter of collection surface per millimetre of rainfall. Besides, most rainwater collection system installers use to assume a capture efficiency of 80%, considering that 20% is lost through evaporation or other means. Thus, the equation to calculate potential rainwater harvested, already introduced in Chap. 4, is:

$$RWH = A \cdot Ap \cdot Rc \cdot E = 96 \cdot 847 \cdot 0.99 \cdot 0.8 \cong 64.4\ m^3$$

Where:

- *RWH* is potential rainwater harvested per year;
- *A* is roof area expressed in square meter;
- *Ap* is the annual precipitation expressed in square mm per year;
- *Rc* is rainfall captured per roof area (0.99L per square meter per millimetre of rain);
- *E* is collection efficiency, namely 80%.

Therefore, considering a roof area approximately equal to 96 m^2, and an average annual precipitation of 847 mm per year recorded in Belgium, on average, 64.4 m^3 of water can be collected per year.

Finally, considering that in three months about 48 m^3 have been used, and approximately three-quarters of them are destined to non-potable uses, the annual amount of non-potable

water used is approximately 144 m^3, it can been assessed that quantity of potential rainwater that can be harvested, account for almost 45% of the total non-potable water used.
The equation to calculate tank size, introduced in Chap. 4, is:

$$V = \frac{RWH \cdot Dp}{365}$$

Where:

- *V* is the volume of the tank estimated;
- *RWH* is potential rainwater harvested;
- *Dp* is the annual dry period, namely amount of weeks or days during which the absence of precipitation can verify, namely 19 days as calculated in Chap. 4;
- *365* are days in a year.

Referring to the case study, the necessary volume of storage tank can be estimate as:

$$V = \frac{64.4 \cdot 19}{365} = 3.35\ m^3$$

Results show that, as explained in the Chap. 4, per 100 m^2 of roof surface, on average 3-5 m^3, as storage volume, are necessary. In this case, considering 96 m^2, 3.35 m^3 are required, namely 3.48 per 100m^2.
In conclusion, considering an average price of 598€ [48] of a tank with a volume of 3406 L (about 180€ per cubic meter), to calculate the simple payback associated with adopting a rainwater harvesting system, not considering cost for installation, it has been estimated that, being the annual saving 290€, collecting annually 64.4 m^3 of rainwater, the payback period accounts for less than two years. However, policy implemented by Flemish Government provides subsidies for the installation of a rainwater harvesting systems, so it could further decrease the payback period.

5.2.1.5 Overall results

In conclusion, Table 5.2 summarizes potential water savings in Bossuwé, assessed considering use of more efficient fixtures and equipment and implementation of best practices, discussed in previous paragraphs.

Table *5.2*: Summary of potential annual water and economic savings

Fitting/process	Strategy	Non-optimised performance (daily)	Optimised performance (daily)	Annual Saving	
				Water (m3)	Euro
Faucet	Using aerators	40 guests x 0,5 min x 8,3 L/minute	40 guests x 0,5 min x 1,9 L/minute	38,91	175,10
Washing dishes	Considering use of dishwasher	50 min x 6 L/minute	8 cycles x 3,8L per rack	81,95	368,81
TOTAL				**120,87**	**543,92**
Non-potable application	Use of rainwater for toilets flushing or cleaning purposes		On average 211 L per day can be harvested and reuse	64,40	289,80

Therefore, only considering installing aerators to reduce water flow from the tap in the public bathroom, and using an efficient dishwasher instead of hand washing in the kitchen, 120.87 m^3 of water can be saved annually, namely 0.39 m^3 per day, more than half of current consumption (Fig. 5.3). In addition, a significant saving could derive from use of rainwater harvested for non-potable use, such like toilets flushing or cleaning purposes. Finally, a further quantity of water could be saved through constant maintenance operations, and encouraging to reduce water consumption, that means sensitization of occupants and employees.

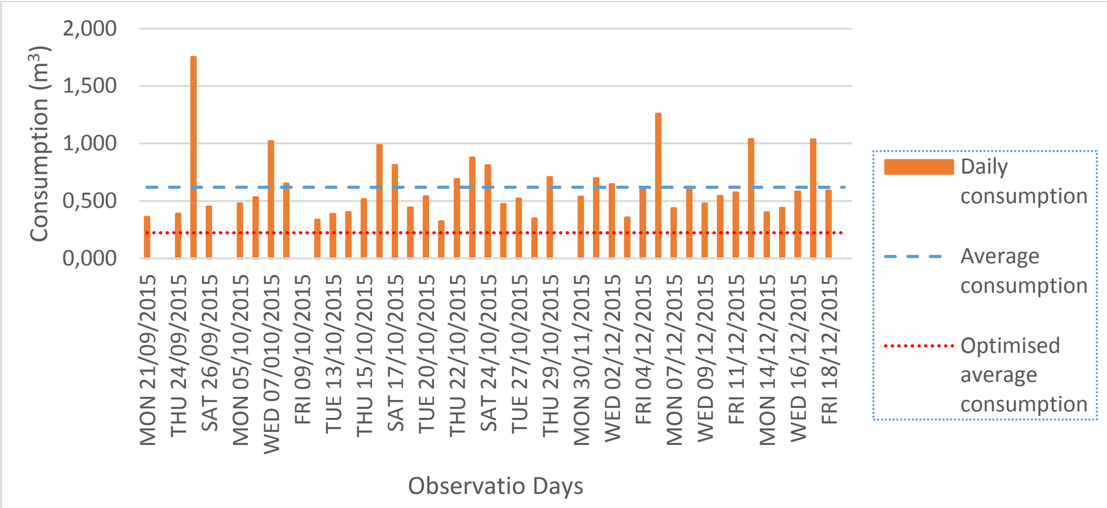

Fig. *5.3*: Comparison between current and optimized daily water consumption in Bossuwé

These data has been evaluated basing on hypothesized calculation (Table 5.3) concerning daily water consumption, taking into account water-using fixtures and equipment currently used in the facility.

Table *5.3*: Daily water consumption hypothesized

Fixtures/ equipment	Total Litres used	Quantity hypothesized		Consumption	
Faucet in the restroom	166	40	users	8,3	L per min
Toilets flushes	75	25	flushes	4	L per flush
Pre rinse spray	300	50	minutes	6	L per min
Hand sink sensor	30	5	minutes	6	L per min
Water cooler	67,5	4,5	hours	15	L per hour
Tot. Hypothesized [L]	**638,5**				
Tot. Calculated [L]	**619,4**				

In the table, it has been considered that single handle faucet in restroom is used by 40 people per day, for 0.5 minutes. Besides, as double flush toilets uses 6 L per full flush, 3 L per reduced flush, an average consumption of 4 L has been counted.

5.2.2 *Second Case Study: Balthazar*

5.2.2.1 Consumption analysis

Café Balthazar is a commercial facility located in the city centre of Kortrijk, that usually works as a restaurant during lunchtime, and a pub during the evening. The building, holds 45 seats in the restaurant, 40 seats upstairs, maximum 100 people in the pub. Peak customers occurs between Saturday and Sunday during the week, instead the peak during the year occurs is almost constant. The business is closed on Tuesday and Wednesday, and it is open every day from 11:00 to 14:00 and in the afternoon from 18:00 to 22:00.

More detailed information about Balthazar are provided in Chap.2 § 2.3.2.

In Balthazar, the indoor demand consists of uses for sanitary, food preparation and cleaning purposes. Data available regard 11 weeks out of 13 (total observation period), but data have been supplied, most of the times, once a week and not always regularly. In the graph below (Fig. 5.4) the trend of daily consumption in function of time has been reported, however is not possible doing consideration about the trend during the week, as daily data are not available.

The average water consumption recorded is 2.433 m^3 per day, namely 2433 L per day.

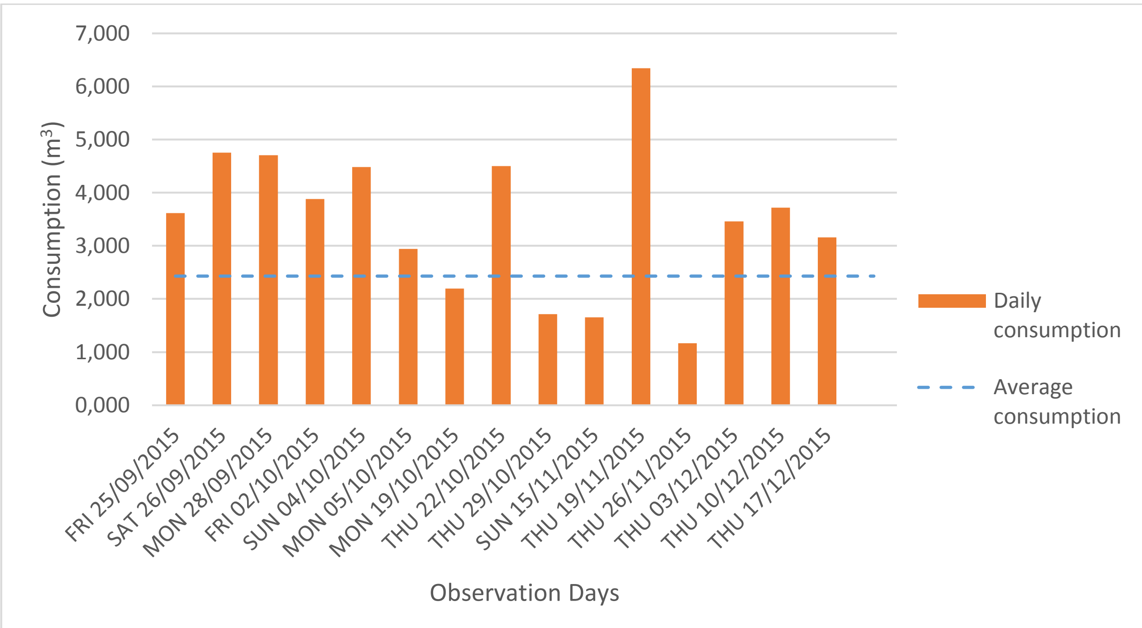

Fig. *5.4*: Daily Water Consumption in Balthazar

Moreover, the number on the water meter after Christmas holidays has been recorded, in order to analyse possible changes in water use. In this case, the facilities was always open during Christmas holidays, therefore evaluating water consumption between 17th December (last day of observation) and 7th January, considering only opening days, the average daily water consumption was 3.419 m^3, namely 0.986 m^3 more than the average daily water consumption during normal days. As it was expected, due to the increased flow of customers during holidays, water consumption is considerably higher.

5.2.2.2 Evaluation of current equipment and possible replacements

It has to be specified that the study refers to the situation analysed in September, at the beginning of the observation period, but starting from October, the building was renewed and the equipment, in the kitchen, has been replaced.

Analysing current equipment situation and evaluating possible replacements, it is possible to find a lot of saving opportunities considering replacement, in fact, facilities have been toured, inventorying water using equipment, and verifying water use, in order to identify potential reduction opportunities.

Particularly, in the public restrooms hand sinks are installed with single handle faucet, made with single-lever control, to adjust water flow and water temperature. Toilets, equipped with double flushing in the ladies'toilets, can be considered an efficient solution in order to improve water management, using 6 L per full flush, 3 L per reduced flush. Finally urinals with sensors are used in gents' toilets.

To increase water efficiency, it is advisable equipping the existing single handle faucet with faucets aerator that, adding air to water, reduces the flow from the tap. The device is available at common ratings of 1.9, 2.8, and 3.8 L/minute [16] and it can be easily found on the market at the average price of 4.50 €, ranging generally from 1 to 10 €. Considering an average existing flow rate of 8.3 L/minute, it is clear that, thanks to the remarkable cut to water used by tap, and to low price, the device yields a payback within a few months. Further information are shown in table 5.4.

In addition, urinals with sensors have no advantages in terms of water efficiency, but only provides health and sanitation benefits, since they are a hands-free option, so it can been replaced by waterless urinals that save significant amounts of water and money. The average price of waterless urinals is 150 € [8], and they do not require a flushing mechanism, so, considering that existing urinals consumption ranges between 7.5L and 11.4L, at least 412

L per day can be saved, namely 1.85 € per day. The evaluation has been done taking into account that every day maximum 70 people arrive to the restaurant at lunchtime, and then 300 in the evening, thus, considering that urinals are used on average 55 times per day.

Concerning kitchen equipment, the pre-rinse spray, equipping the single compartment sink, represents a high-efficiency device, using from 6 to 10 L per minute, while conventional sprayers use between 9.5 and 15 L of water per minute. [16] However, in order to optimize the efficiency, it is a good practice inspecting periodically the working of the devices, avoiding limescale formation, that could restrict the flow, and checking for leaks. In the kitchen, there is also a small hand sink whit sensor that can be considered an efficient option as it activates water flow only in the presence of hands, using on average 6 L/minute. Another small sink is used to wash vegetables or food in general, it is equipped with a conventional single hand faucet with flow rates ranging from 11.4 to 18.9 L/minute. [16] For kitchen faucet retrofits, it is possible installing aerators that achieve a flow rate of 8.3 L/minute. These devices have to be inspected periodically to avoid scale buildup. [14] In the bar there is a double compartment sink, equipped with a conventional double hand faucet, assuming that also in this case flow rates range from 11.4 to 18.9 L/minute, and considering that the sink is filled about 4 times per day, a considerable reduction of water use, can be reached using aerators.

Moreover, the kitchen is equipped with two food warming machines (of which technical data have not been taken into account) and two dishwashers, both undercounter models. Analyzing datasheet of one of them, it can be noted that the consumption amounts to 3L per cycle, thus, being the other one similar to the first, but not having available datasheet, it is assumed that consumption is the same for both.

In addition, there are two ice machines, consulting datasheet of similar models of the same brand, it can be considered that the small one can produce almost 25 kg of ice, and the bigger one 193 kg. As it has been said in Chap.2, the amount of water used depends on the quality of water supplied to facilities and on the desired end quality of ice, therefore, the average amount of water required for ice-making process, ranges from 57L to more than 190L per 45 kg of ice. It can be assumed a consumption of 57L per 45 kg of ice produced, namely the minimum consumption, as the facility is equipped with a water softener, located in the basement, improving quality of water. In order to optimize and increase machines efficiency it is a good habit to clean it, to avoid limescale formation, keep ice machine’s coils clean to guarantee an efficient working, to ensure the appropriate temperature inside the machine.

5.2.2.3 Implementation of correct standards of behaviour

In addition to installation of water-efficient fixtures and equipment, a cost-effective way aimed to reduce water consumption and to limit waste, is the implementation of correct standards of behavior. One of them is educating building occupants and employees on using water efficiently, for instance running dishwashers only with full load, carrying out operation and maintenance procedures. Considering the kitchen, best practices include washing only full load when using the dishwasher, pre-soaking utensils to reduce the amount of water required for cleaning, filling the sink and turning off the taps while soaping dishes. In the public restroom it is convenient installing low flow faucets (as was mentioned in the previous paragraph), and doing maintenance procedures regularly in order to ensure maximum efficiency, checking for leaks, and inspecting fixtures to avoid scale formation that could restricted flow.
On the other hand, it is important to sensitize customers, using brochures and promotional materials to encourage them to reduce water use, for example turning the tap off when it is not being used, or avoiding flushing without the need.

5.2.2.4 Potential Rainwater reuse

In Balthazar, harvested rainwater can represent a valid alternative to freshwater used for non-potable applications, as it can be used in domestic activities such as toilets flushing or cleaning purposes. It should be stated that the building has not green areas, therefore, use of rainwater for landscape irrigation is not expected.
Also in this case, as the building is located just in the city centre, not having sufficient space for the installation of an underground tank, it is advisable to adopt an aboveground rainwater tank, choosing appropriately the size, according to requested needs. As it has been said in the previous chapter, generally, roofs are preferable as catchment surface, as water collected is cleaner. Besides, in order to improve rainwater quality, a first flush water diverters should be adopt, to remove the first flush of a rain event that may contain contaminants from the roof, avoiding to let they enter in the tank.
Using the same formula introduced in Chap. 4, the potential rainwater harvested is calculated as:

$$RWH = A \cdot Ap \cdot Rc \cdot E = 150 \cdot 847 \cdot 0.99 \cdot 0.8 \cong 100.6\, m^3$$

The equation to calculate tank size, introduced in Chap. 4, is:

$$V = \frac{RWH \cdot Dp}{365} = \frac{100.6 \cdot 19}{365} = 5.23\ m^3$$

Results show that, as explained in the Chap. 4, per 100 m^2 of roof surface, on average 3-5 m^3, as storage volume, are necessary. In this case, considering 150 m^2, 5.23 m^3 are required, namely 3.48 per 100m^2.

In conclusion, considering an average price of 710€ [48] of a tank with a volume of 5678 L (about 135€ per cubic meter), to calculate the simple payback associated with adopting a rainwater harvesting system, not considering cost for installation, it has been estimated that, being the annual saving 452.70€, collecting 100.6 m^3 of rainwater, the payback period accounts for one year and half. However, policy implemented by Flemish Government provides subsidies for the installation of a rainwater harvesting systems, so it could further decrease the payback period.

5.2.2.5 Overall results

In conclusion, Table 5.4 summarizes potential water savings in Balthazar, assessed considering use of more efficient fixtures and equipment and implementation of best practices, discussed in previous paragraphs.

Table *5.4*: Summary of potential annual water and economic savings

Fitting/process	**Strategy**	**Non-optimised performance (daily)**	**Optimised performance (daily)**	**Annual Saving**	
				Water (m3)	**Euro**
Faucets	Using aerators	140 guests x 0,5 min x 8,3 L/minute	140 guests x 0,5 min x 1,9 L/minute	82,22	369,97
Urinals	Considering use of waterless urinals	55 L x 7,5 L per flush	no flushing mechanism	107,66	484,48
Sub-total restroom				**189,88**	**854,45**
Single handle Faucet	Using aerators	15 min/day x 11,4 L/minute	15 min/day x 8,3 L/minute	12,14	54,61
Faucet in the bar	Using aerators	20 min/day x 11,4 L/minute	20 min/day x 8,3 L/minute	16,18	72,82

Sub-total kitchen			**28,32**	**127,43**
TOTAL			**218,20**	**981,88**
Non-potable application	Use of rainwater for toilets flushing or cleaning purposes	On average 385 L per day can be harvested and reuse	100,62	452,81

Therefore, considering these simple interventions to make more efficient the equipment in the building, 218.20 m^3 of water can be saved annually, namely 0.83 m^3 per day, almost half of current consumption. The graph below shows in more immediate way the significant lowering in water consumption (Fig. 5.5). In addition, a significant saving could derive from use of rainwater harvested for non-potable use, such like toilets flushing or cleaning purposes. Finally, a further quantity of water could be saved implementing correct standards of behaviour mentioned before.

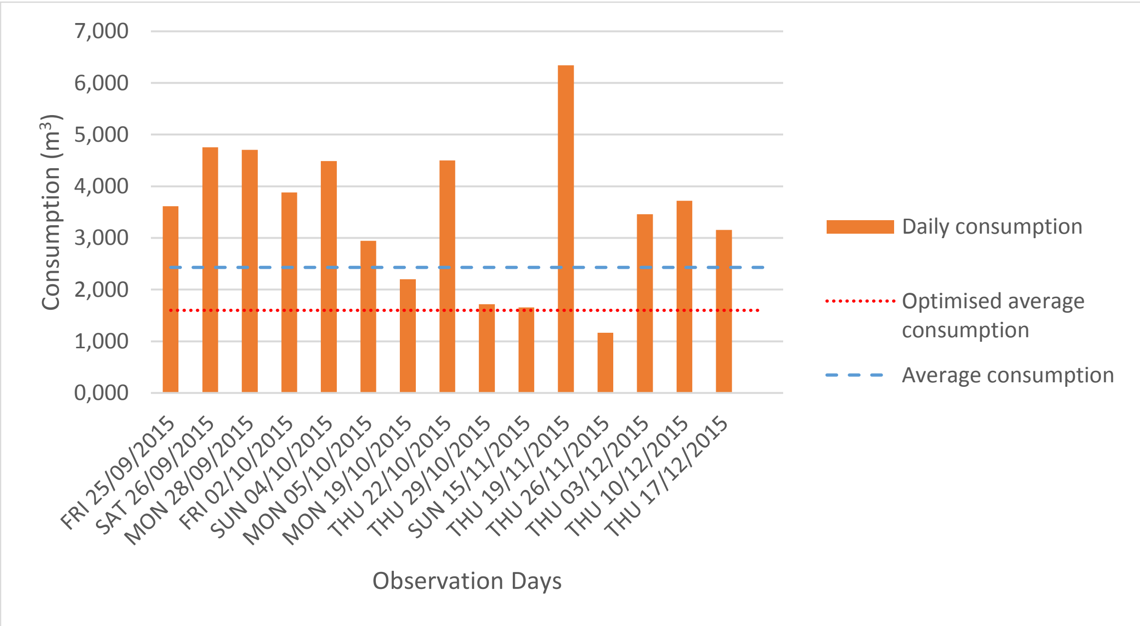

Fig. *5.5*: Comparison between current and optimized daily water consumption in Balthazar

These data has been evaluated basing on hypothesized calculation (Table 5.5) concerning daily water consumption, taking into account water-using fixtures and equipment currently used in the facility.

Table 5.5: Daily water consumption hypothesized

Fixtures/ equipment	Total Litres used	Quantity hypothesized		Consumption	
Pre rinse spray	300	50	minutes	6	L per min
Hand sink sensor (kitchen)	60	10	minutes	6	L per min
Single handle faucet (kitchen)	171	15	minutes	11,4	L per min
Double handle faucet (bar)	228	20	minutes	11,4	L per min
Two dishwashers	60	10	cycles	3	L per cycle
Two iIce machines	253,3	200	kg of ice	1,27	L per Kg
Toilet flushes	280	70	flushes	4	L per flush
Urinals flushes	412,5	55	flushes	7,5	L per flush
Single handle faucets (restroom)	581	140	users	8,3	L per min
Other	86,7				
Tot. Hypothesized [L]	**2345,8**				
Tot. Calculated[L]	**2432,6**				

In the table, dishwashers consumption has been calculated considering overall 6 cycles (2 per hour) at lunchtime and 4 in the evening. For single handle faucets in restrooms, 0.5 minutes per person have been hypothesized. Besides, as double flush toilets uses 6 L per full flush, 3 L per reduced flush, an average consumption of 4 L has been counted.

5.2.3 Third Case Study: Hotel Messeyne

5.2.3.1 Consumption analysis

Hotel Messeyne, a four-star hotel located in the city center in Kortrijk, represents an interesting case study, as it offered the possibility to study a more complex building, holding both rooms and restaurant, as well as other services for its customers.
The indoor demand consists of uses for sanitary, food preparation, cleaning purposes. Data available regard the whole observation period, but they have been collected once a week for the most part of the observation period.
In the graph below (Fig. 5.6), the trend of daily consumption in function of time has been reported. From the analysis, it can be seen that there are not strong variations in water

consumption, in fact, as owners anticipated, values recorded are almost constant, oscillating between a maximum consumption of 9.67 m^3 to a minimum of 5.52 m^3, with an average water consumption of 7.617 m^3 per day, namely 7617 L per day. Due to restricted availability of data, it has not been possible to analyse the trend of water consumption during the week, to verify possible peaks.

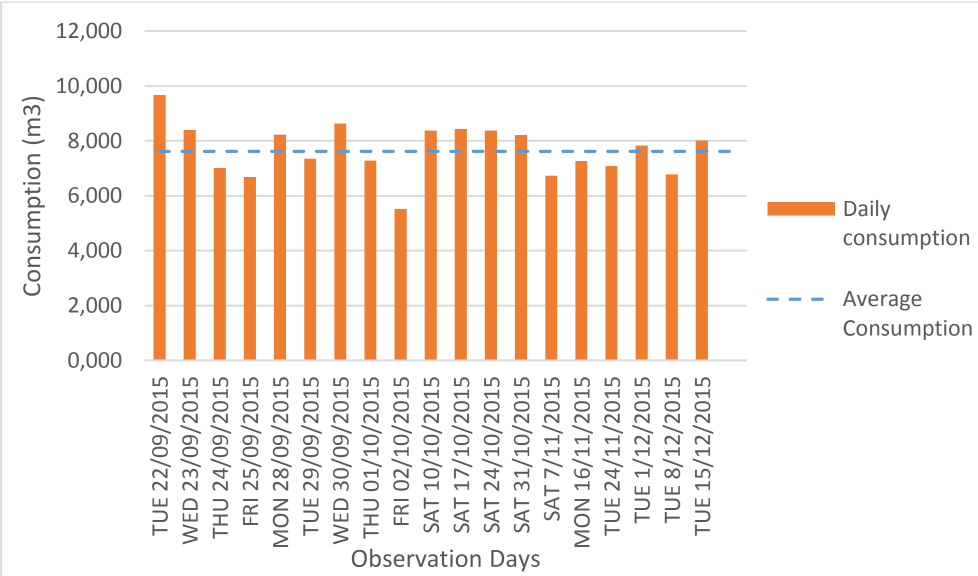

Fig. *5.6*: Daily Water Consumption in Hotel Messeyne

Moreover, the number on the water meter after Christmas holidays has been recorded, in order to analyse possible changes in water use. In this case, the facilities was closed from 25th to 3rd January, therefore evaluating water consumption between 15th December (last day of observation) and 5th January, considering only opening days, the average daily water consumption was 8.39 m^3, namely 0.77 m^3 more than the average daily water consumption during normal days.

5.2.3.2 Evaluation of current equipment and possible replacements

Touring the facility and analysing current equipment situation, possible interventions have been evaluated, but replacements have not been considered, as most of the fixture can be evaluated as new, thus, sufficiently efficient in order to minimize water consumption.

However, inventorying water using equipment and looking for interventions to make more efficient facility in terms of water management, some saving opportunities have been found considering retrofitting current fixtures with more efficient devices.

The structure is built on three levels, holding 26 rooms, the restaurant seating 40 people, the kitchen, public restrooms and the laundry. Finally, there are also two meeting rooms, the fitness room and a wellness area not taken into account, due to lack of data.
Touring the building several using-water devices have been found: starting from the public restroom, there are ladies' toilets equipped with double flushing, that can be considered an efficient solution using 6 L per full flush, 3 L per reduced flush, while in gents'toilets there are urinals with sensors. Finally, single handle faucets are installed for hand sinks. Also in this case, to increase water efficiency, it is advisable equipping the existing single handle faucets with faucets aerator that, adding air to water, reduces the flow from the tap, reaching an average consumption of 1.9, 2.8, and 3.8 L/minute. [16] Considering an average existing flow rate of 8.3 L/minute, it is clear that, thanks to the remarkable cut to water used by tap, and to low price, the device yields a payback within a few months. Further information are shown in table 5.6. Another possibility could be an infra-red sensor control of taps, though, as it has been explained in Chap.3, it does not provide particular advantages for water saving, but provides sanitation benefits in public use facilities.
In addition, urinals with sensors have no advantages in terms of water efficiency, but only provides health and sanitation benefits, since they are a hands-free option, so it can been replaced by waterless urinals that save significant amounts of water and money. The average price of waterless urinals is 150 € [8], and they do not require a flushing mechanism, so, they represent a valid alternative to the existing urinals with a consumption ranging between 7.5L and 11.4L per flush.
The laundry, located in another wing of the building, consists in a washing machine and a dryer (detailed reported in Chap.2, Table 2.2) necessary for the cleaning of the linen used in the restaurant and in the rooms. Not having available data about consumption it will be considered that for small-scale laundry, water efficiency washing machines have an average water consumption of 7L per kg laundry washed. Calculation will take into account a load capacity of 10 kg, as has been read from the datasheet of the machine.
Regarding private rooms, it had been possible to analyze fixtures and equipment in two different rooms. Focusing on private bathrooms features, in both there are a double sinks with single handle faucets, also in this case the average existing flow rate of 8.3 L/minute can be decreased installing aerators, achieving an average consumption of 1.9, 2.8, and 3.8 L/minute. Toilets equipped with double flushing have not need to be replaces, being an efficacious solution. Regarding water use by toilets, calculation are referred to a study of water use in hotels, according to toilets cisterns are discharged on average six times per day,

assuming four flushes per guest per night, plus two flushes per occupied room per day during cleaning. [8] In addition, in the first room, there are both the bathtub, with a single-handled tub faucet, and the shower with a double rain shower and the same single-handled faucet.
In the other room there is only the bathtub with the single-handled tub faucet, equipped with a single rain shower, to serve also as shower. Being fixtures almost new, for showerheads can be considered a flow rate of 7 L/minute characterizing high efficient devices.
Finally, investigating the kitchen, equipment consists in a single dishwasher and two sinks to clean. The first one has a single compartment and is equipped with a faucet constituted by a long hose and multi-option spray head, for it, a consumption ranging from 6 to 10 L per minute will be considered. While, for the second, double compartment, sink, equipped with double handle faucet, a consumption of 11.4 to 18.9 L/minute will be considered, providing for the possibility to install aerators achieving a flow rate of 8.3 L/minute. These devices have to be inspected periodically to avoid scale buildup. Concerning dishwasher, a stationary door type, analysing datasheet, it is possible to calculate the daily water consumption due to it, considering a consumption of 2.8 L per cycle.

5.2.3.3 Implementation of correct standards of behaviour

Implementation of correct standard of behavior, especially for a hotel, represents an important step to improve significantly water management.
In a facility where a substantial part of consumption is due to guests, first step is educating them using water efficiently through initiatives and programs that must be explained to visitors and customers, also using brochures and promotional materials. It is important sensitizing guests, encouraging them taking shorter showers, avoiding faucets from running longer than necessary, turning the tap off during sanitation activities when it is not being used (for instance brushing teeth), avoiding flushing without the need. It is fundamental letting they know that saving water is a common interest, due to a common issue.
For instance, in Chap.3 Water Pebble has been introduced, as small circular gadget has to be placed near the plughole of the shower, measuring and memorizing the amount of water used. Working as a traffic light, it allows to shorten shower than 3 minutes and a half, helping guests to know when the amount of water required is exceeded. Probably, in a four-star hotel, it could prove inelegant, but certainly, guests would appreciate the advance management, and the efforts done in order to avoid waste, saving water and energy.

About kitchen, best practices include washing only full load when using the dishwasher, pre-soaking utensil to reduce the amount of water required for cleaning, filling the sink and turning off the taps while soaping dishes.

In the bathroom it is convenient doing maintenance procedures regularly in order to ensure maximum efficiency, checking for leaks, and inspecting fixtures to avoid scale formation that could restricted flow.

Finally, simple behaviors should be implemented also for laundry, first of all, selecting the most efficient washing machines, ensuring they are used with full loads, minimizing the length of the rinse cycle, using high-efficiency detergents. Besides, using cotton-polyester with lower laundry energy demands (compared with pure cotton) and encouraging guests to reuse towels and bed linens in order to reduce laundry volume.

5.2.3.4 Potential Rainwater reuse

In Hotel Messeyne the indoor demand consists of uses for sanitary, food preparation and cleaning purposes. In this regard, due to the high daily consumption registered, harvested rainwater could be used for non-potable applications such like toilets flushing or cleaning purposes. It should be stated that the building has not green areas, therefore, use of rainwater for landscape irrigation is not expected.

Also in this case, as the building is located just in the city centre, not having sufficient space for the installation of an underground tank, it is advisable to adopt an above ground rainwater tank, choosing appropriately the size, according to requested needs. As it has been said in the previous chapter, generally, roofs are preferable as catchment surface, as water collected is cleaner. Besides, in order to improve rainwater quality, a first flush water diverters should be adopt, to remove the first flush of a rain event that may contain contaminants from the roof, avoiding to let they enter in the tank.

Using the same formula introduced in Chap. 4, the potential rainwater harvested is calculated as:

$$RWH = A \cdot Ap \cdot Rc \cdot E = 166.25 \cdot 847 \cdot 0.99 \cdot 0.8 \cong 111.52\ m^3$$

The equation to calculate tank size, introduced in Chap. 4, is:

$$V = \frac{RWH \cdot Dp}{365} = \frac{111.52 \cdot 19}{365} = 5.80\ m^3$$

Results show that, as explained in the Chap. 4, per 100 m^2 of roof surface, on average 3-5 m^3, as storage volume, are necessary. In this case, considering 166.25 m^2, 5.80 m^3 are required, namely 3.48 per 100m^2. In conclusion, considering an average price of 635€ [48] of a tank with a volume of 5867 L (about 110€ per cubic meter), to calculate the simple payback associated with adopting a rainwater harvesting system, not considering cost for installation, it has been estimated that, being the annual saving 501.84€, collecting 111.52 m^3 of rainwater, the payback period accounts for 15 months, namely little bit more than one year. However, policy implemented by Flemish Government provides subsidies for the installation of a rainwater harvesting systems, so it could further decrease the payback period.

5.2.3.5 Overall results

In conclusion, Table 5.6 summarizes potential water savings in Hotel Messeyne, assessed considering use of more efficient fixtures and equipment and implementation of best practices, discussed in previous paragraphs.

Table *5.6*: Summary of potential annual water and economic savings

Fitting/process	Strategy	Non-optimised performance (daily)	Optimised performance (daily)	Annual Saving	
				Water (m3)	Euro
Faucet	Using aerators	75 guests x 0,5 min x 8,3 L/minute	75 guests x 0,5 min x 1,9 L/minute	81,12	365,04
Urinals	Considering use of waterless urinals	30 L x 7,5 L per flush	no flushing mechanism	76,05	342,23
Sub-total public restroom				**157,17**	**707,27**
Faucet	Using aerators	19 guests x 6 min x 8,3 L/minute	19 guests x 6 min x 1,9 L/minute	246,60	1109,72
Sub-total private restroom				**246,60**	**1109,72**
Double handle Faucet	Using aerators	40 min/day x 11,4 L/minute	40 min/day x 8,3 L/minute	41,91	188,60
Sub-total kitchen and bar				**41,91**	**188,60**
TOTAL				**445,69**	**2005,59**
Non-potable application	Use of rainwater for toilets flushing or cleaning purposes		On average 329 L per day can be harvested and reuse	111,52	501,86

Therefore, considering these simple interventions to make more efficient the equipment in the building, 445.69 m^3 of water can be saved annually, namely 1.31 m^3 per day. The graph below shows in more immediate way the significant lowering in water consumption (Fig. 5.7). In addition, a significant saving could derive from use of rainwater harvested for non-potable use, such like toilets flushing or cleaning purposes. Finally, a further quantity of water could be saved implementing correct standards of behaviour mentioned before.

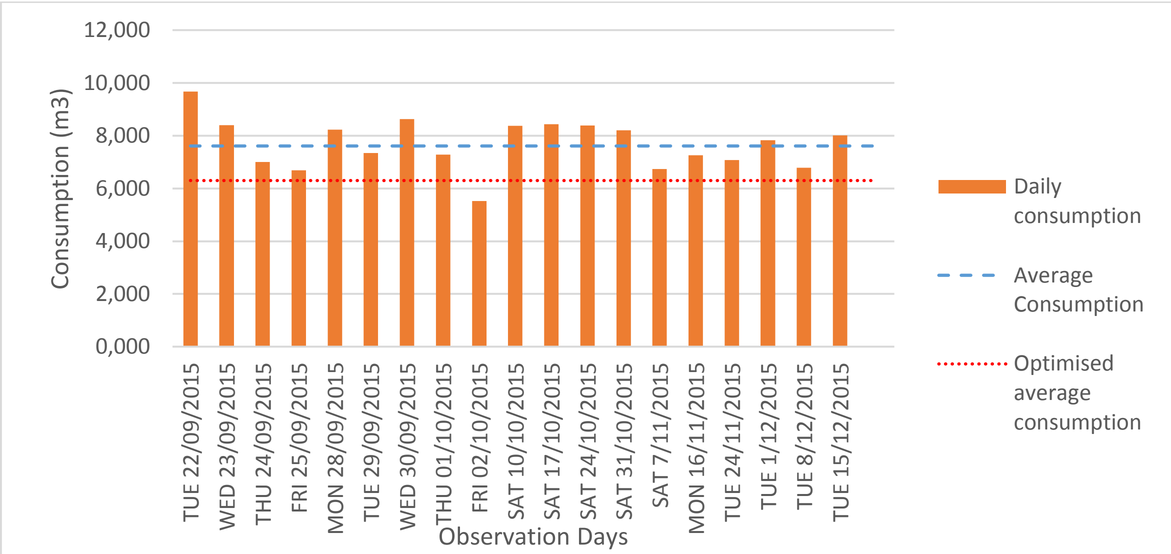

Fig. *5.7*: Comparison between current and optimized daily water consumption in Hotel Messeyne

These data has been evaluated basing on hypothesized calculation (Table 5.7) concerning daily water consumption, taking into account water-using fixtures and equipment currently used in the facility.

Table *5.7*: Daily water consumption hypothesized

Fixtures/ equipment	Total Litres used	Quantity hypothesized		Consumption	
Pre rinse spray	420	70	minutes	6	L per min
Double handle faucet (kitchen)	456	40	minutes	11,4	L per min
Dishwasher	33,6	12	cycles	2,8	L per cycle
Toilet flushes (public restroom)	140	35	flushes	4	L per flush
Urinals	225	30	flushes	7,5	L per flush
Faucets in public restroom	311,3	75	users	8,3	L per min
Faucets in private bathroom	473,1	114	minutes	8,3	L per min
Toilet flush in private bathroom	304	76	flushes	4	L per flush

Room cleaning	90	30	flushes	3	L per flush
Showerhead in private bathroom	1995	285	minutes	7	L per min
Washmachine	140	2	cycles	70	L per cycle
Other	3028,9				
Tot. Hypothesized [L]	**4588,0**				
Tot. Calculated [L]	**7616,9**				

In public restrooms and private bathrooms in the rooms, as double flush toilets uses 6 L per full flush, 3 L per reduced flush, an average consumption of 4 L has been counted. Besides, use of faucets by 75 people in public restroom is hypothesized, considering restaurant open for lunch and dinner. Faucets consumption in private bathroom has been calculated considering 570 guests per month, namely 19 daily, using faucet 6 minutes per day. Moreover, regarding flushes, as it has been mentioned previously, four flushes per day per guest and two flushes per day per occupied room (considering cleaning of 15 rooms) have been counted. Finally, showerhead consumption in private bathroom includes 19 guests per 15 minutes per day, where 15 minutes represent an average time between shower and bath. Also in this case for faucets in public restrooms 0.5 minutes per person have been hypothesized and regarding washmachine a consumption of 7 L of water per kg has been counted, thus, considering a capacity load of 10 kg, an average consumption of 70 kg has been calculated daily.

5.2.4 Fourth Case Study: Restaurant Lindenhof

5.2.4.1 Consumption analysis

The restaurant Lindenhof is located in a large structure made up of a restaurant, a bar and banquet rooms, with an overall surface of 1200 m^2, holding until 540 seats.
The indoor demand consists of uses for sanitary, food preparation, cleaning purposes while, in spite of the presence of green areas around the building, watering is provided by rainwater, as there is not an irrigation system.
In this case it was possible studying meticulously trend of water consumption, thanks to large availability of data that regard the whole observation period (starting from 23rd of September to 20th December), and have been provided daily by personnel.
In the graph below (Fig. 5.8) the trend of daily consumption in function of time has been reported. From the analysis, it can be seen that values recorded are quite constant during the

week, but highly variable during weekend, oscillating between a maximum consumption of 7.31 m^3, registered on 24th November, to a minimum of 0.28 m^3, recorded on 13th October, with an average water consumption of 2.85 m^3 per day, namely 2855 L per day. This value has been obtained, taking into account that the facilities is closed once a week, on Monday. Moreover, from the graph, it is possible to see particularly high values of water consumption, thus, in order to justify them, during the observation period, clarification have been asked to the owner. Mostly, this values can be traced to private party hosted in the facilities, or particularly crowded evenings (especially during weekends). For examples, on Sunday 25th October, 4.55 m^3 have been registered, it was due to two private parties, on Friday 20th November, the restaurant was busy, registering a water consumption of 4 m^3, the same happened on Tuesday 1st December, when a consumption of 6.51 m^3 was reordered. In opposition, on Wednesday 14th October, a consumption of 0 m^3 was registered, as the stuff worked in another building and the restaurant remained closed.

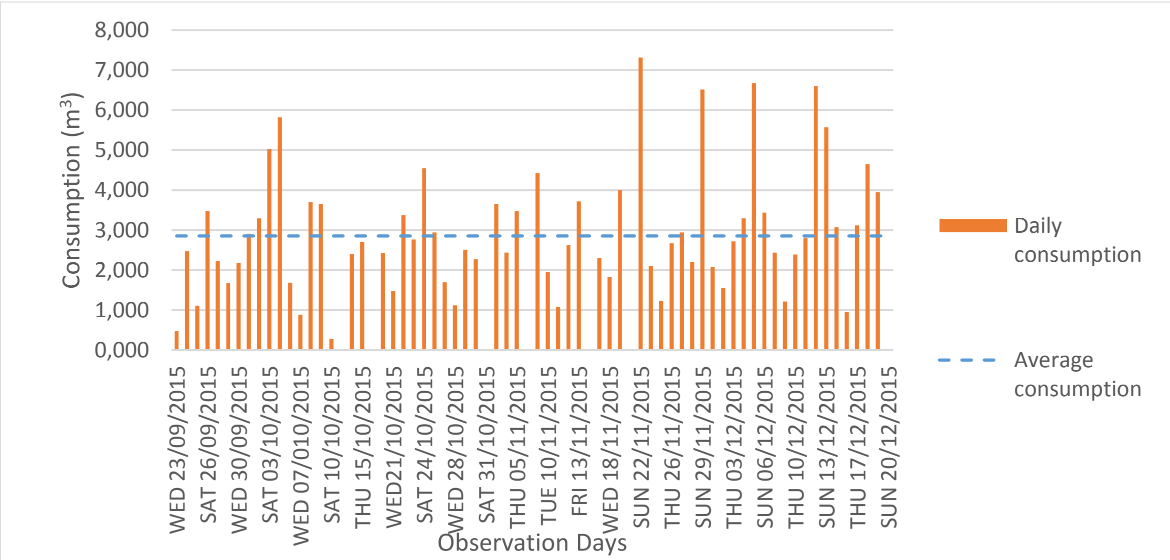

Fig. *5.8*: Daily Water Consumption in Lindenhof

Moreover, the number on the water meter after Christmas holidays has been recorded, in order to analyse possible changes in water use. In this case, restaurant provided data from 26th, therefore evaluating water consumption between 20th December (last day of observation) and 26th December, considering only opening days, the average daily water consumption was 2.70 m^3, in this case lower than average water consumption during normal days.

5.2.4.2 Evaluation of current equipment and possible replacements

Touring the facility and analysing current equipment situation, several saving opportunities have been found, due to the large number of water-using fixtures, equipment and systems. Moreover, possible replacements have been evaluated, in order to make more efficient facility in terms of water management.

Starting from the public restroom, there are ladies' toilets equipped with single flushing, while in gents'toilets there are urinals with sensors. Sinks in party room have timed-flow pillar tap (with a push down time-flow control and self-closing function) that averagely deliver water for 15 seconds, while sink in the hall and in the café are equipped with sensors. Single flushing toilets do not represent an efficient solution using more than 13L per flush, therefore replacing them with low-flow toilets can provide an important opportunities for water saving within facilities (considering an average cost of 150€ for a new low-flush toilet). Double flushing toilet, in fact, can be considered an efficient fixture using 6 L per full flush, 3 L per reduced flush. Also in this case, to increase water efficiency, it is advisable replacing urinals with sensors (that have no advantages in terms of water efficiency, but only provides health and sanitation benefits, since they are a hands-free option) by waterless urinals that save significant amounts of water and money. The average price of waterless urinals is 150 € [8], and they do not require a flushing mechanism, so, they represent a valid alternative to the existing urinals with a consumption ranging between 7.5L and 11.4L per flush. Regarding self-closing faucets in the party room, and infrared sensors installed in the café, it is advisable equipping them with faucets aerator that, adding air to water, reduces the flow from the tap, reaching an average consumption of 1.9, 2.8, and 3.8 L/minute [16]

Considering an average existing flow rate of 8.3 L/minute, it is clear that, thanks to the remarkable cut to water used by tap, and to low price, the device yields a payback within a few months. Further information are shown in table 5.8.

However, to reduce water consumption, maintenance is fundamental: particularly, for tank-type toilets installed in the restaurant, it is important checking periodically valve functioning and water level. Besides, checking for leaks could help to reduce considerably water consumption within the facility.

In the café there are two double compartment sinks mainly used to wash glasses, one equipped with single handle faucet, and the other with double handle faucet. Assuming for both a conventional consumption ranging from 11.4 to 18.9 L/minute, in order to obtain a considerable reduction of water it is possible installing aerators that achieve a flow rate of 8.3 L/minute.

Touring the kitchen, two hand sinks used by personnel, equipped with sensors have been found, representing an efficient option as they activate water flow only in the presence of hands, using on average 6 L/minute. Moreover, in the kitchen there are five double compartment sinks equipped with double handle faucet, used for food preparation or cleaning purposes. For them same considerations done for the faucet in the bar are valid. In addition, there are two more sinks both equipped with long hose and multi-option spray head, one of them with a double compartment, while the other, single compartment, uses rainwater to clean part of the kitchen. They represent high-efficiency devices, using from 6 to 10 L per minute, compared to conventional sprayers use between 9.5 and 15 L of water per minute. [16] In calculation it will be considered that one of them uses only rainwater for cleaning purpose, therefore city water consumption is evaluated as null.

Finally, the facilities holds three dishwashers, one of them used exclusively to wash glasses. All three are stationary door types and, analysing datasheet, it is possible to evaluate the daily water consumption, necessary for calculation, considering a consumption of 3L, 2.6L and 2.8L per cycle.

5.2.4.3 Implementation of correct standards of behaviour

To improve water use, reducing waste, saving-water initiatives and programs have to be adopt and must be explained to customers, using brochures and promotional materials that encourage water use reductions. Thus, also in this case, sensitization of guests and employees is fundamental. In fact, simple actions as running dishwashers only with full load, using dual flush toilets, avoiding flushing without the need, are simple behaviors that can produce significant water savings.

About kitchen, best practices include washing only full load when using the dishwasher, pre-soaking utensil to reduce the amount of water required for cleaning, filling the sink and turning off the taps while soaping dishes.

In the public restroom, it is convenient installing low flow faucets, and doing maintenance procedures regularly in order to ensure maximum efficiency, checking for leaks, and inspecting fixtures to avoid scale formation that could restricted flow.

5.2.4.4 Potential Rainwater reuse

In Lindenhof, use of rainwater is already implemented for cleaning purpose in the kitchen, in fact, rainwater is treated through an underground system that uses carbon to filter it. However, use of harvested rainwater can extended to different purposes as alternative to potable water use, for domestic activities such like toilets flushing or cleaning purposes, as well as for irrigation during dry period. As it has been said previously, Lindenhof does not use an irrigation system to water the surrounding green area, relying only on rainwater. However, during dry period, with long absences of rains, it could be necessary provide watering, using potable water. For this purpose, in the following paragraph a rainwater harvesting system will be calculated, eventual used both for irrigation of green areas during the summer and cleaning purposes for the rest of the year.

In this case, thanks to the presence of a wide green area around the building, the installation of an underground tank could be possible (according to the nature of soil), choosing appropriately the size and shape, generally the cylindrical one is the most common.

This system would require only a conveyance system, and a storage tank, to provide non-potable applications in restrooms and kitchen and a simple irrigation system.

Also in this case, in order to improve rainwater quality, a first flush water diverters should be adopt, to remove the first flush of a rain event that may contain contaminants from the roof, avoiding to let they enter in the tank.

Using the same formula introduced in Chap. 4, the potential rainwater harvested is calculated as:

$$RWH = A \cdot Ap \cdot Rc \cdot E = 272 \cdot 847 \cdot 0.99 \cdot 0.8 \cong 182.46\ m^3$$

Due to the large dimension of the building, only a wing of the building has been taken into account, considering roof area approximately equal to 272 m^2, in this way, on average, 182.46 m^3 of water can be collected per year.

Finally, it has been calculated that, on average, 33 m^3 are used per year during summer days namely 207L per day. Considering a flow rates of 8.3 L per minute, and taking into account that every day 25 minutes are spent to water plants (from April to September), it can been assessed that quantity of rainwater used to water, accounts for almost 35% of the total potential rainwater harvested.

The equation to calculate tank size, introduced in Chap. 4, is:

$$V = \frac{RWH \cdot Dp}{365} = \frac{182.46 \cdot 19}{365} = 9.5\ m^3$$

Results show that, as explained in the Chap. 4, per 100 m^2 of roof surface, on average 3-5 m^3, as storage volume, are necessary. In this case, considering 272 m^2, 9.5 m^3 are required, namely 3.49 per 100m^2.

In conclusion, considering an average price of 2856€ of a tank with this volume [49] (about 300€ per cubic meter), to calculate the simple payback associated with adopting a rainwater harvesting system, not considering cost for installation, it has been estimated that, being the annual saving 821.09€, collecting 182.5 m^3 of rainwater, the payback period accounts for three years and half. However, policy implemented by Flemish Government provides subsidies for the installation of a rainwater harvesting systems, so it could further decrease the payback period.

5.2.4.5 Overall results

In conclusion, Table 5.8 summarizes potential water savings in Lindenhof, assessed considering use of more efficient fixtures and equipment and implementation of best practices, discussed in previous paragraphs.

Table *5.8*: Summary of potential annual water and economic savings

Fitting/process	Strategy	Non-optimised performance (daily)	Optimised performance (daily)	Annual Saving	
				Water (m3)	**Euro**
Toilets	Replacing with double flush toilets	50 guests x 13 L per flush	50 guests x 4 L per flush	140,85	633,83
Urinals	Considering use of waterless urinals	45 L x 7,5 L per flush	no flushing mechanism	105,64	475,37
Faucet (self-closing)	Using aerators	60 guests x 15 sec x 8,3 L/minute	60 guests x 15 sec x 1,9 L/minute	30,05	135,22
Faucet (sensors)	Using aerators	40 guests x 0,5 min x 8,3 L/minute	40 guests x 0,5 min x 1,9 L/minute	17,80	80,11
Sub-total public restroom				**294,34**	**1324,52**
Faucets café	Using aerators	30 min/day x 11,4 L/minute	30 min/day x 8,3 L/minute	29,11	130,99
Double handle Faucets	Using aerators	75 min/day x 11,4 L/minute	75 min/day x 8,3 L/minute	72,77	327,48

Sub-total café and kitchen				**72,77**	**327,48**
TOTAL				**367,11**	**1651,99**
Irrigation	Use of rainwater for irrigation	25 min/day x 161 days x 8,3 L/minute		33,40	150,33
Non-potable application	Use of rainwater for toilets flushing or cleaning purposes		On average 583 L per day can be harvested and reuse	182,46	821,09

Therefore, considering these simple interventions to make more efficient the equipment in the building, 367.11 m^3 of water can be saved annually, namely 1.17 m^3 per day (considering opening days). As it is possible to see from the tables, from April to September, 207 L per day are used watering plants (25 min/day x 8.3 L/minute), as 583 L of rainwater could be harvested daily, remaining 375.5 L per day could be used for domestic purposes during dry period. On the contrary, whole 583 L could be used during the rest of the year.

The graph below shows in more immediate way the significant lowering in water consumption (Fig. 5.9). In addition, a significant saving could derive from use of rainwater harvested for non-potable use, such like toilets flushing, cleaning purposes and irrigation. Finally, a further quantity of water could be saved implementing correct standards of behaviour mentioned before.

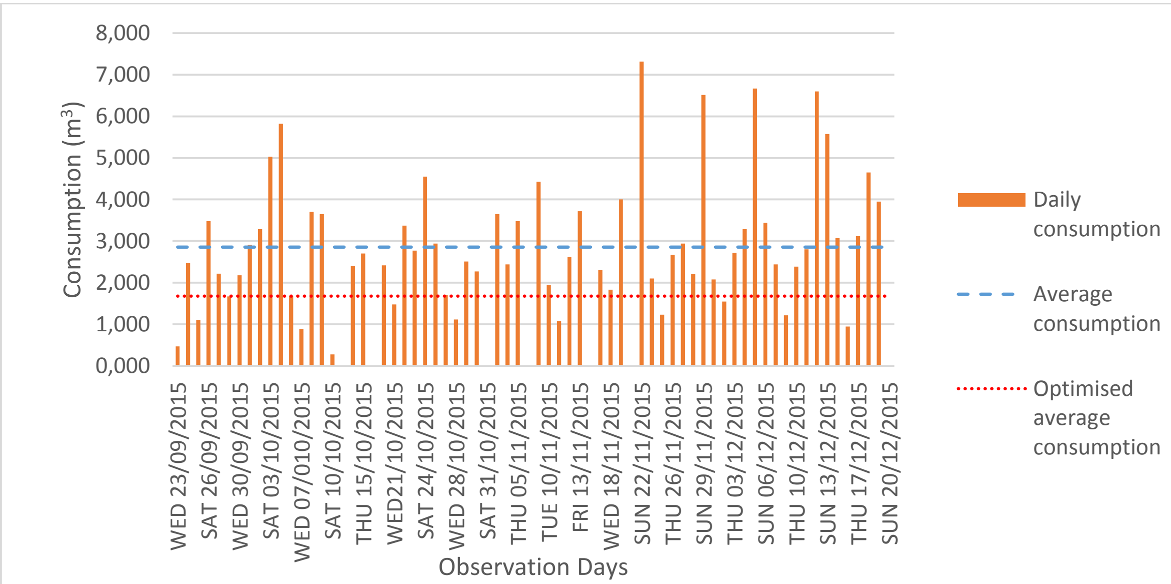

Fig. *5.9*: Comparison between current and optimized daily water consumption in Lindenhof

These data has been evaluated basing on hypothesized calculation (Table 5.9) concerning daily water consumption, taking into account water-using fixtures and equipment currently used in the facility.

Table *5.9*: Daily water consumption hypothesized

Fixtures/ equipment	Total Litres used	Quantity hypothesized		Consumption	
Toilet flush in public bathroom	650	50	flushes	13	L per flush
Urinals	337,5	45	flushes	7,5	L per flush
Faucet restroom (timed-flow pillar tap)	124,5	60	users	2,1	L per min
Faucet restroom (sensors)	166	40	users	8,3	L per min
2xFaucets café	342	30	minutes	11,4	L per min
2xPre rinse spray	270	45	minutes	6	L per min
5xDouble handle faucet (kitchen)	855	75	minutes	11,4	L per min
2xHand sink sensor (kitchen)	120	20	minutes	6	L per min
Dishwasher 1	18	6	cycles	3	L per cycle
Dishwasher 2	16,8	6	cycles	2,8	L per cycle
Dishwasher 3	10,4	4	cycles	2,6	L per cycle
Tot. Hypothesized [L]	**2910,2**				
Tot. Calculated [L]	**2853,4**				

In public restrooms, it has been hypothesized that single flush toilets are used 50 times considering both lunchtime and dinnertime. In addition, regarding timed-flow pillar tap consumption has been calculated considering a working of 15 seconds and a flow rate of 8.3 L/minute. Also in this case for faucets with sensor in public restrooms 0.5 minutes per person have been hypothesized.

5.2.5 Fifth Case Study: Restaurant Koevert

5.2.5.1 Consumption analysis

In Koevert, the indoor demand consists of uses for sanitary, food preparation, cleaning purposes and landscaping irrigation. Data available regard the whole observation period (starting from 23rd of September), in fact, data about daily consumption have been registered everyday by the personnel, thus this allowed to have regularly available data for the study. In the graph below (Fig. 5.10) the trend of daily consumption in function of time has been reported. From the analysis, it can be seen that values recorded are almost constant, oscillating between a maximum consumption of 3 m^3 to a minimum of 1 m^3, with an average water consumption of 1.702 m^3 per day, namely 1702 L per day. This value has been obtained, taking into account that the facilities is closed twice a week, on Saturday and Sunday.

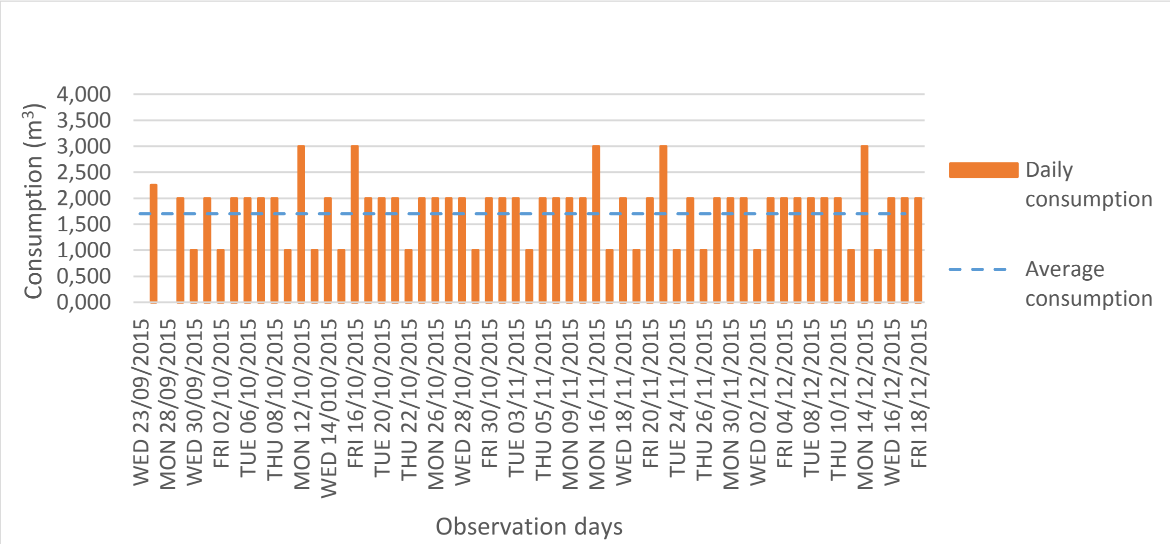

Fig. *5.10*: Daily Water Consumption in Koevert

Moreover, the number on the water meter after Christmas holidays has been recorded, in order to analyse possible changes in water use. In this case, the facilities was closed from 26th to 4th January, therefore evaluating water consumption between 18th December (last day of observation) and 5th January, considering only opening days, the average daily water consumption was 2.4 m^3, namely 0.698 m^3 more than the average daily water consumption during normal days.

5.2.5.2 Evaluation of current equipment and possible replacements

Touring the facility and analysing current equipment situation, possible replacements have been evaluated, in fact inventorying water-using equipment and looking for interventions to make more efficient facility in terms of water management, some saving opportunities have been found.

The structure consists of an outdoor terrace, provided with a garden (mainly used during the summer) and an interior room of 180 m^2 that holds the café, the lunchroom, the kitchen, the restroom and the laundry. Several using-water devices have been found in the building: starting from the public restroom, there are ladies' toilets equipped with double flushing, that can be considered an efficient solution using 6 L per full flush, 3 L per reduced flush, while in gents'toilets there are urinals with sensors. Finally, single handle faucets are installed for hand sinks. Also in this case, to increase water efficiency, it is advisable equipping the existing single handle faucets with faucets aerator that, adding air to water, reduces the flow from the tap, reaching an average consumption of 1.9, 2.8, and 3.8 L/minute [16]

Considering an average existing flow rate of 8.3 L/minute, it is clear that, thanks to the remarkable cut to water used by tap, and to low price, the device yields a payback within a few months. Further information are shown in table 5.10.

In addition, urinals with sensors have no advantages in terms of water efficiency, but only provides health and sanitation benefits, since they are a hands-free option, so it can been replaced by waterless urinals that save significant amounts of water and money. The average price of waterless urinals is 150 € [8], and they do not require a flushing mechanism, so, they represent a valid alternative to the existing urinals with a consumption ranging between 7.5L and 11.4L per flush.

Regarding bathroom used by personnel, it is equipped with older and less efficient fixtures: there are an older sink with double handle faucet, to regulate water flow and water temperature, and a toilet equipped with single flushing. Older conventional faucet flow rates can range from more than 11L/minute to 19L/minute [16], but water saving can be achieved, also in this case, by retrofitting existing faucets with aerators. Alternatively, another solution could be replacing existing faucet, considering that for low-flow basin taps the price ranges between 100 and 200€. [8] The toilet used by personnel is a tank-type toilet, old fixtures like this, generally, use more than 13L per flush, therefore replacing them with low-flow toilets can provide an important opportunities for water saving within facilities (considering an average cost of 150€ for a new low-flush toilet). Another possibility to increase water efficiency of tank-type toilet, is using a cistern-volume-reducing device, (mentioned in Chap.2 §3.2.1.1) that allows to reduce the filling volume of the tank up to 2.83L.

To reduce water consumption, maintenance is essential: particularly, for tank-type toilets it is important checking periodically valve functioning and water level. Besides, checking for leaks could help to considerably reduce water consumption within the facility.

The laundry, located in the restroom used by personnel, consists in a washing machine and a dryer (detailed reported in Chap.2, Table 2.2) necessary for the cleaning of the linen used in the restaurant. Not having available data about consumption it will be considered that for small-scale laundry, water efficiency washing machines have an average water consumption of 7L per kg laundry washed. Facility is also equipped with a small ice machine, for which the same consideration made earlier will be take into account.

Regarding the café, located in the lunchroom, it is equipped with a double compartment sink with double handle faucet, and an undercounter dishwasher, mainly to wash glasses, using softened water. Assuming that the double handle faucet has a conventional consumption ranging from 11.4 to 18.9 L/minute, it is possible installing aerators that achieve a flow rate of 8.3 L/minute, to obtain a considerable reduction of water. Concerning undercounter dishwasher, analysing datasheet, it is possible to calculate the daily water consumption due to it, considering a consumption of 2.4 L per cycle.

Finally, touring the kitchen, it can be found a single compartment sink with double handle faucet, used to wash kitchenware, whereby same considerations done for the faucet in the bar are valid. A second single compartment sink with long hose and multi-option spray head is used to clean, for it, it will be consider a consumption ranging from 6 to 10 L per minute. In the kitchen there is another dishwasher, a stationary door type, analysing datasheet, it is possible to calculate the daily water consumption due to it, considering a consumption of 3 L per cycle.

In another wing of the kitchen there is a third sink, double compartment, with double handle faucet, to wash vegetables, whereby a consumption of 11.4 to 18.9 L/minute will be considered, providing for the possibility to install aerators achieving a flow rate of 8.3 L/minute. These devices have to be inspected periodically to avoid scale buildup.

5.2.5.3 Implementation of correct standards of behaviour

In addition to installation of water-efficient fixtures and equipment, a cost-effective way aimed to reduce water consumption and to limit waste, is the implementation of correct standards of behavior. First step could be educating occupants and employees on using water efficiently, for instance running dishwashers and washing machines only with full load, carrying out operation and maintenance procedures. About kitchen, best practices include washing only full load when using the dishwasher, pre-soaking utensil to reduce the amount of water required for cleaning, filling the sink and turning off the taps while soaping dishes.

In the public restroom it is convenient installing low flow faucets (as it is said in the previous paragraph), and doing maintenance procedures regularly in order to ensure maximum efficiency, checking for leaks, and inspecting fixtures to avoid scale formation that could restricted flow.
On the other hand, it is important sensitize customers, using brochures and promotional materials to encourage them to reduce water use, for example turning the tap off when it is not being used, or avoiding flushing without the need.
In addition, a key factor regarding water consumption is irrigation: Koevert, in fact, holds wide green area, considering that the surface of the whole lot accounts for 4800 m^2. There is no irrigation system, as during the winter, the garden is watered naturally by rains. However, during summer irrigation operations are made using city water. About that, several measures can be carried out in order to avoid providing irrigation system with potable water, minimising the overall water consumption. First of all, it could be advantageous to instal systems supplied by harvested rainwater (next paragraph focuses on it). Another important measure that can be implemented is the installation of controlled drip-irrigation systems with electronic controllers and moisture sensors that prevent irrigation cycles when the soil is already wet. In addition, an appropriate garden design and a correct choice of plants, low water using and drought resistant plants, can contribute significantly to reduce irrigation needs. Plants and trees appropriate in Flemish Region have been reported in Chap.3 §3.2.5. Considering the installation of an irrigation system, it is advisable installing device to control sprinklers working, equipped with sensors to avoid operation during natural precipitations.

5.2.5.4 Potential Rainwater reuse

In Koevert, harvested rainwater can represent a key alternative to potable water used for irrigation during dry period, as well as for domestic activities such like toilets flushing or cleaning purposes.
In this case, thanks to the presence of a wide green area around the building, the installation of an underground tank could be possible (according to the nature of soil), choosing appropriately the size and shape, generally the cylindrical one is the most common. Doing a benefit-cost analysis, if a complete irrigation system proves too expensive, compared to the irrigation needs, centred only in summer period, it is possible evaluate a simple system using rainwater harvested from the roof, as Fig. 5.11 shows. This simple system would require

only a conveyance system, and a storage tank, without considering an articulated irrigation system based on sophisticated technologies.

Also in this case, in order to improve rainwater quality, a first flush water diverters should be adopt, to remove the first flush of a rain event that may contain contaminants from the roof, avoiding to let they enter in the tank.

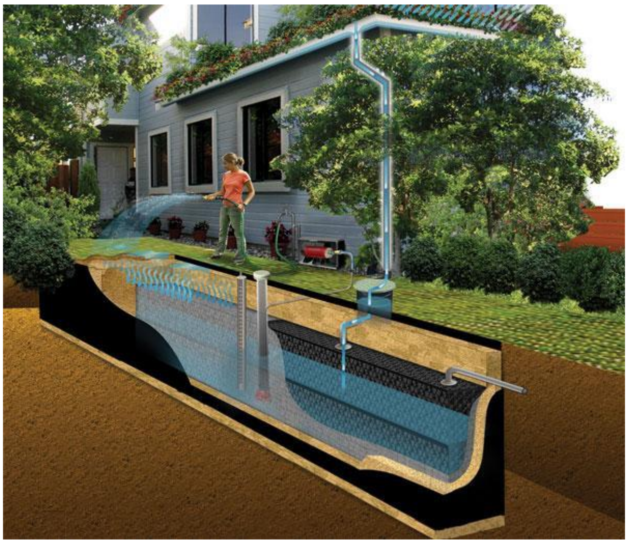

Fig. 5.11: Example of simple irrigation system using rainwater

Source: www.homeimprovementpages.com

Using the same formula introduced in Chap. 4, the potential rainwater harvested is calculated as:

$$RWH = A \cdot Ap \cdot Rc \cdot E = 85 \cdot 847 \cdot 0.99 \cdot 0.8 \cong 57\ m^3$$

Considering only irrigation needs, in calculations only a wing of the building has been taken into account, considering roof area approximately equal to 85 m^2, in this way, on average, 57 m^3 of water can be collected per year.

Finally, it has been calculated that, on average, 22 m^3 are used per year to water during summer days, namely 124L per day. Considering a flow rates of 8.3 L per minute, and taking into account that every day 15 minutes are spent to water plants (from April to September), considering only watering the terrace, it can been assessed that quantity of rainwater used to water, accounts for almost 39% of the total potential rainwater harvested.

The equation to calculate tank size, introduced in Chap. 4, is:

$$V = \frac{RWH \cdot Dp}{365} = \frac{57 \cdot 19}{365} = 2.96\ m^3$$

Results show that, as explained in the Chap. 4, per 100 m^2 of roof surface, on average 3-5 m^3, as storage volume, are necessary. In this case, considering 85 m^2, 9.5 m^3 are required, namely 3.48 per 100m^2.

In conclusion, considering an average price of 773€ of a tank with this volume [49], (namely 261€ per cubic meter) to calculate the simple payback associated with adopting a rainwater harvesting system, not considering cost for installation, it has been estimated that, being the annual saving 256.50€, collecting 57 m^3 of rainwater, the payback period accounts for three years. However, policy implemented by Flemish Government provides subsidies for the installation of a rainwater harvesting systems, so it could further decrease the payback period.

5.2.5.5 Overall results

In conclusion, Table 5.10 summarizes potential water savings in Koevert, assessed considering use of more efficient fixtures and equipment and implementation of best practices, discussed in previous paragraphs.

Table *5.10*: Summary of potential annual water and economic savings

Fitting/process	Strategy	Non-optimised performance (daily)	Optimised performance (daily)	Annual Saving	
				Water (m3)	Euro
Faucet	Using aerators	80 guests x 0,5 min x 8,3 L/minute	80 guests x 0,5 min x 1,9 L/minute	63,49	285,70
Urinals	Considering use of waterless urinals	25 L x 7,5 L per flush	no flushing mechanism	46,50	209,25
Sub-total public restroom				**109,99**	**494,95**
Faucet	Using aerators	7 employees x 0,5 min x 11 L/minute	7 employees x 0,5 min x 1,9 L/minute	7,90	35,54
Toilets	Using a cistern-volume-reducing device	7 employees x 13 L per flush	7 employees x (13-2,83) L per flush	4,91	22,11
Sub-total private restroom				**12,81**	**57,65**
	Using aerators	15 min/day x 11,4 L/minute	15 min/day x 8,3 L/minute	11,53	51,89

Double handle Faucet 1					
Double handle Faucet 2	Using aerators	15 min/day x 11,4 L/minute	15 min/day x 8,3 L/minute	11,53	51,89
Faucet in the bar	Using aerators	20 min/day x 11,4 L/minute	20 min/day x 8,3 L/minute	15,38	69,19
Sub-total kitchen and bar				**38,44**	**172,98**
TOTAL				**161,24**	**725,58**
Irrigation	Use of rainwater for irrigation	15 min/day x 135 days x 8,3 L/minute		16,81	75,63
Non-potable application	Use of rainwater for toilets flushing or cleaning purposes		On average 230 L per day can be harvested and reuse	57,02	256,59

Therefore, considering these simple interventions to make more efficient the equipment in the building, 161.24 m^3 of water can be saved annually, namely 0.65 m^3 per day. As it is possible to see from the tables, from April to September, 124.5 L per day are used watering plants (15 min/day x 8.3 L/minute), as 230 L of rainwater could be harvested daily, remaining 105.5 L per day could be used for domestic purposes during dry period. On the contrary, whole 230 L could be used during the rest of the year.

The graph below shows in more immediate way the significant lowering in water consumption (Fig. 5.12). A significant saving could derive from use of rainwater harvested for irrigation purposes. Finally, a further quantity of water could be saved implementing correct standards of behaviour mentioned before.

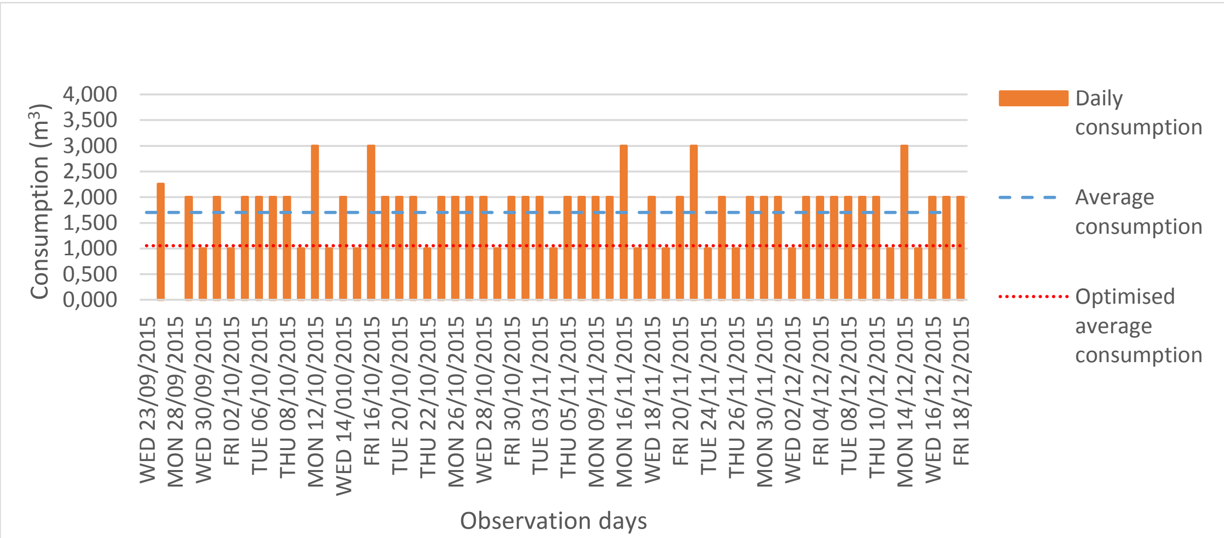

Fig. *5.12*: Comparison between current and optimized daily water consumption in Koevert

These data has been evaluated basing on hypothesized calculation (Table 5.11) concerning daily water consumption, taking into account water-using fixtures and equipment currently used in the facility.

Table *5.11*: Daily water consumption hypothesized

Fixtures/ equipment	Total Litres used	Quantity hypothesized		Consumption	
Pre rinse spray	240	40	minutes	6	L per min
Double handle faucet (bar)	228	20	minutes	11,4	L per min
Double handle faucet (kitchen)1	171	15	minutes	11,4	L per min
Double handle faucet (kitchen)2	171	15	minutes	11,4	L per min
Dishwasher bar	14,4	6	cycles	2,4	L per cycle
Dishwasher kitchen	30	10	cycles	3	L per cycle
Ice machine	31,7	25	kg of ice	1,3	L per Kg
Toilet flush in public bathroom	160	40	flushes	4	L per flush
Urinals	187,5	25	flushes	7,5	L per flush
Faucet in public bathroom	332	80	users	8,3	L per min
Faucet in private bathroom	38,5	7	users	11	L per min
Toilet flush in private bathroom	91	7	flushes	13	L per flush
Washmachine	35	0,5	cycles	70	L per cycle
Tot. Hypothesized [L]	**1730,1**				
Tot. Calculated [L]	**1702,5**				

In public restrooms, as double flush toilets uses 6 L per full flush, 3 L per reduced flush, an average consumption of 4 L has been counted. Also in this case for faucets in public restrooms 0.5 minutes per person have been hypothesized and regarding washmachine a consumption of 7 L of water per kg has been counted, thus, considering a capacity load of 10 kg, an average consumption of 70 kg has been calculated daily.

Conclusions

The aim of this work was to analyze water consumption in hospitality facilities, considering the possibility of reducing consumption, identifying saving opportunities, and evaluating the effectiveness of actions taken for this purpose.

Thanks to gathering of data, it has been possible to assess the consumption before and after retrofitting. In particular, results show the importance of using water-saving fixtures, equipment and systems, using less water, performing as well as or better than conventional models currently used.

It is clear that important results can be reached acting on sanitary fixtures and kitchen equipment, as have been discussed in the last section. For example, considering simple retrofitting or replacement as using low flow faucets in kitchen and restroom, waterless urinals, double flush toilets. In addition, implementing corrects practices, as taking shorter showers, running dishwashers and washing machines only with full load, avoiding faucets from running longer than necessary, turning the tap off during sanitation activities, avoiding flushing without the need, selecting the most efficient machines, implementing operation and maintenance procedures. Finally, it has been proved that reusing rainwater could represent an effective way to improve management, avoiding using city water for non-potable application as domestic activities, such as toilets flushing or cleaning purposes, and for irrigation needs especially during dry periods.

Calculations have been done considering only retrofitting and replacement interventions. Results show that in each study case a substantial percentage of current average water consumption could be saved, in some cases more than half of the current average consumption, and, consequently, a significant amount of money. Moreover, even if it was not possible to evaluate precisely costs and benefits related to rainwater reuse, as the work did not focus on the design of a complete system, it is expected that significant amount of water, collected from roof surface, could be harvested and reuse, supplying non-potable applications. For each business, the quantity of potential rainwater harvested has been calculated, and results show that it represents a conspicuous percentage of city water currently used for non-potable applications.

Concluding, this thesis focuses on five cases study, but it was developed with the more general purpose of providing available and useful information to managers, encouraging sustainable management, good practices and standards related to the concept of Green.

These considerations may be particularly relevant and actual in a reality, both for Belgium, where cost of water is among the highest in Europe, and worldwide, where water issue is becoming more and more pressing.

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