# OPTIMIZATION OF THE WATER CYCLE IN THE "HOUSE OF THE FUTURE" OF THE UNIVERSITY OF AVEIRO

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## Abstract

The University of Aveiro, in association with a group of interested enterprises, has been developing a project for a “House of the Future”, based on the concept of Green Building. This house should integrate the actual needs of buildings according to sustainable construction standards. The project aims to develop not only breakthrough technologies but also environmentally-friendly technologies. One of the major concerns is the optimization of the water cycle in the house, through re-using and recycling water. Trying to use as little water from main supply network as possible, the system should incorporate rainwater and saltwater and utilize low-flow fixtures.

## 1. Introduction

Aveiro (Portugal), the home-town of the University of Aveiro, is located 250 km north of Lisbon and 10 km from the Atlantic coast (Figure 1). The surrounding area is the Aveiro Salt Lagoon ("Ria de Aveiro") which covers 110 $km^2$ (more than 27 000 acres), between the land and the ocean (Figure 2) in the estuary of the Vouga River. The Aveiro region is part of the economically dynamic northern coastal strip of the country. The region is characterized by a significant number of industrial sectors covering all kinds of activities, including the manufacture of goods and provision of services for civil engineering, and house construction and furnishing.


Figure 1 – Location of Aveiro

The University of Aveiro was founded in 1973, and since then it has come to be considered one of the most dynamic and innovative universities of Portugal. This university has an international reputation for academic excellence, research, innovation, state-of-the-art technology and cultural intervention.

The University of Aveiro is the only Portuguese university belonging to the ECIU – European Consortium of Innovative Universities, a consortium that has, over the years, worked on a number of activities within the fields of Education, Research, Regional Development and Institutional Development.

The reputation that the University of Aveiro has been achieving has enabled many innovative projects to be developed. This is part of an institutional strategy to stimulate applied thematic research through interdisciplinary and interdepartmental cooperation, with the collaboration of regional and national industry. Knowing that university-industry relations help to fill the gap between academic research and technology development and market applications, the University of Aveiro is trying to improve these relations by creating enlarged and multidisciplinary projects.

Figure 2 – “Ria de Aveiro”

The project “House of the Future” is an example of that strategy. This research project is an interdisciplinary and inter-institutional network composed of 12 enterprises plus the University of Aveiro, through many of its academic departments. The “House of the Future” co-operation network was created in 1999, in the Aveiro Region, the main promoter being the University of Aveiro.

In this work, emphasis is given to the proposal for water use in the house, as well as to the equipment and treatment units designed to reduce water consumption.

Even though the “House of the Future” is analyzed in terms of its integration in the region of Aveiro, its main innovative aspects can be applied in many other locations as well.

## 2. The Aveiro's "House of the Future" Project

It is well known that the concept of green building places a high priority on health, the environment and resources' conservation performance over the building's life-cycle. The green building is essentially concerned with:

- reducing human exposure to toxic materials;
- conserving non-renewable energy and scarce materials;
- minimizing life-cycles' ecological impact on energy and materials used;
- using renewable energy and materials that are sustainably harvested;
- protecting and restoring local air, water, soils, flora and fauna.

These priorities expand and complement the classical main building design concerns: economy, utility, durability and delight.

Some of these ideas, like preventing negative impacts on the environment and ensuring a healthy and pleasant place for users, along with lower utilization and maintenance costs for the owner, are the headlines of the University of Aveiro's "House of the Future" project.

In practice, the strategic goals of the project are to innovate in the habitat field and to create conditions to build, in the near future, a possible House of the Future. It is clear that the house must have an advanced design, but the most important target is to build according to sustainable construction standards, assuring a good interaction with local ecosystems and improving the indoor environment (air quality, noise, temperature, humidity, light, etc.). Another major concern is to cut consumption of essential resources, mainly by means of reused and/or recycled materials, renewable energies and by optimizing the water cycle.

The project involves academic researchers and practitioners from different academic and industrial sectors, related in some degree to the habitat. The enterprises involved in the project, are mainly involved in constructing and furnishing houses and other buildings. Only by combining the efforts of all the main participants engaged in constructing houses can both an effective modernization of the habitat sector and sustained innovation in current and future houses be achieved. Thanks to its diversified and important industry, the Aveiro region is an excellent setting for the development of this network.

The network has evolved and become a formal association, called AveiroDOMUS, whose statutory objectives are "the promotion and dissemination of theoretical, scientific and technological innovation related to new products and processes related to the habitat field, particularly by creating the necessary conditions to design and build a structure called House of the Future".

The "House of the Future" will serve as a living laboratory for research and development, open to the public and to industry, and it will provide a framework for continuous product and process innovation.

The project of the "House of the Future" is quite ambitious. It aims to evoke new visions, new solutions and new products in any field that impacts on the design, construction and furnishing of houses, and to apply them to advanced constructions.

The AveiroDOMUS network decided to start by establishing a set of functional principles that the house should obey, and it then drafted a conceptual sketch of the House. The conceptual draft

revealed a house made up of three modules. At any moment, one of those modules would be habitable, and would indeed be inhabited on a permanent basis, or bookable for short periods of time. All devices and systems, even those still in prototype form, are to be fully functional. Another module will exhibit and explain the innovative products, processes and solutions used in the first one. Finally, the third module will be under adaptation, receiving new and more innovative products, in order to replace the first one as the next inhabitable module. This cycle is to be repeated on a rotational basis, thereby ensuring that the house will always be “of the Future”.

The first phase of the project (currently underway) has been devoted to the identification and development of futuristic products, systems, solutions and construction methods that will be incorporated into the first version of the house. The second phase, which partly occurs in parallel with the first, is dedicated to the various plans and blueprints necessary to build the house. In the third and final phase the overall construction plan of the “house of the future” is implemented, and the house is built. The first two phases include the activities described below:

*Phase 1: Identification and development of innovative products, systems and construction methods*

1. Futuristic ideas generation: creativity sessions involving participants from other areas of competence and other disciplines, aiming to obtain as many innovative ideas as possible for the development of new products, processes and solutions, and to consolidate the house’s conceptual framework.
2. Classification of ideas: organizing the ideas generated in the ideas generation activity according to different perspectives, providing inputs for the different purposes and perspectives.
3. Selection of ideas: using non-systematic or intuitive approaches, combined with other more structured techniques (multi-criteria matrix), to converge to a number of viable ideas (given the skills and interests of enterprises and university departments).
4. New products and new systems specification: formal evaluation and description of selected ideas in order to open a new product or new system file.
5. New product and new systems development: developing the new products and new systems with the support of systematic methodologies.

*Phase 2: Preparation and integration of plans and blueprints*

6. Preparation of thematic plans and blueprints (sub-projects): specification of a number of subprojects, corresponding to each of the thematic specialities that form the overall construction plan. These subprojects will be developed in parallel with the previous phase. They will both influence and be influenced by the development of new products, systems and construction methods.
7. Construction Plans: integration and harmonization of all the subprojects in a unique global construction Plan.

The idea generation phase was very fruitful. Brainstorming and brainwriting exercises held in the university and in the enterprises yielded more than 700 ideas. The productivity of those exercises is in part due to the multidisciplinary character of the teams. The various creativity sessions carried out in the university involved professors from 12 departments; those carried out in the enterprises involved employees with different backgrounds and responsibilities, as well as the managers and directors.

The ideas generation and ideas classification activities have been completed. The selection of ideas activity is actually an ongoing process that has already been initiated by all the enterprises belonging to AveiroDOMUS.

At present, the emphasis is on the specification of new products and systems, and on the preparation of the construction sub-projects.

The third and final phase is the construction of the house. Present plans envisage construction starting in 2007.

Some sustainability requisites are regarded as essential, such as the recycling and the re-use of the house's resources: the house should act as an efficient re-usage system; the house must not be aggressive to the environment; the house should be economical, minimizing energy losses and maximizing energy re-usage; non-polluting energy sources of different natures will be used.

The Construction Plans of the first version of the House of the Future are divided into twenty-two sub-projects, to be developed by different teams, for example Architecture, Air Quality, Domotics, Energy and Water Supply and Drainage.

## 3. The water cycle in the "House of the Future"

Portugal is a country in the southern part of Europe. At the moment, in average years, it enjoys a positive hydric balance (available fresh water supply is greater than needs), but it is forecast that the country may suffer a lack of water in the medium term, even in average years.

Agriculture is involved in over 70% of water consumption, all too often through techniques lacking any kind of sophistication. Industry accounts for around 20% of consumption, and household supply uses less than 10%.

Even though the hydric balance is positive in average terms, there are, nonetheless, spatial and temporal distribution problems. In terms of space, the hydrographic basins in the north of Portugal, which enjoy a greater influence from the Atlantic, benefit from high rainfall, putting them in a very favorable position vis-à-vis availability and needs.

In the south, which has a Mediterranean climate, critical situations often occur, especially in dry years. Some studies have been carried out with the aim of moving water between hydrographic basins, to solve this problem.

At any rate, a climate that is temperate and Mediterranean, albeit with an Atlantic influence, translates into cold winters and hot, dry summers. It should be noted, however, that this situation leads to certain problems with the utilization of rainwater, since it is only available for part of the year. Although the flow of the main rivers is controlled by dams, these are often multi-purpose (power, irrigation and public supply), at local level the storage of winter rainfall for all-year use is still not considered to be economically viable.

The south and west of the country are washed by the Atlantic ocean, yet desalination is not regarded as a useful option for obtaining drinking water. This is not only because the (average) hydric balance is still positive, but also due to the fact that it is still cheaper, in Portugal, to produce / use safe drinking water than to embark on desalination. But, with pollution increasingly occurring at the source -

implying higher treatment costs - and the increased consumption predicted for the coming years, the possibility of desalination is accepted as being likely in the future, in some parts of the country.

It is, in any case, true that the efficient use of water is today a national priority. This is the main reason why the optimization of the water cycle in the house is the major concern of the “water supply and drainage” subproject of the House of the Future.

The idea is to create a system that recycles wastewater and re-uses it in other parts of the house, simultaneously with the application of low-flow fixtures and the use of saltwater and rainwater, thus reducing the use of main water to the minimum. The inclusion of a non-desalinated saltwater supply line is one solution which, in a likely scenario of scarce fresh water, could be an interesting alternative in coastal regions (like Aveiro) for purposes that do not require water of a particularly high quality. The concept could also be useful further inland, in situations when, rather than saltwater, poorer quality water could be used - water taken directly from rivers, lakes, etc. The use of saltwater, though it gives rise to problems in terms of treatment - is currently used in many parts of the world, including Hong Kong, the Gulf States, and so forth. It can help to solve many water problems in those coastal regions.

In this paper, the concept of water recycling consists of re-using treated wastewater for various purposes, like toilet flushing (one of the biggest uses of water in a typical house). It is known that recycled water can satisfy most water demands, as long as it is treated to ensure water quality appropriate for the use in question. In addition to provide a reliable, locally-controlled water supply, water recycling offers various environmental benefits. By providing an additional source of water, water recycling helps to decrease the diversion of water from sensitive ecosystems. Other benefits include decreasing wastewater discharges and reducing and preventing pollution. It must be borne in mind that, by implementing successful water-efficiency strategies which minimize the amount of drinking water that a municipality must provide, we are also leading to more stable water charges. Facilities that use water efficiently can reduce costs through lower water use charges, lower sewerage charges, lower use of energy and chemicals, and lower capacity charges and limits.

In terms of outside sources, the use of saltwater, rainwater and even, obviously, water from the public supply system is considered, even though this may not be of safe drinking quality.

It should be noted that the idea of supplying water that is not of safe drinking quality through the mains supply system, but with safeguards for public health, is currently a strategic option being discussed in Europe for the near future, along with local treatment facilities for drinking water and the exclusive use of bottled water for this purpose.

Regarding the reduction of consumption, the goal is to cut the current consumption figures of over 150 l/day per person to below 100 l/day. Among the several solutions for reducing consumption being considered for the House of the Future are the following:

- small volume water closet tanks;
- low-flow fixtures;
- timer or automatic control devices;
- air emulsifiers;
- waterless urinals;
- low consumption washing machines

Within this goal of consumption reduction, special attention will be given to water closet tanks, the flushing of which can be responsible for significant waste (accounting for up to 30 or 40% of total consumption in the residential sector, according to some authors). The volume of water closet tanks in Europe, initially over 15 liters, has progressively been reduced to 12 l, 9 l and 6 l, with current models in northern countries holding as little as 2 l and even a little as 1.5 l.

Figure 3 shows the scheme of principle which is now being studied for the water supply of the House of the Future. It should be pointed out that the final scheme might differ from this one, given that technical and economical viability studies are still being carried out for several components of the system, especially some of the treatment systems.

The use of wastewaters will require adequate storage and treatment systems so that water in sufficient quantity and of adequate quality will be available for subsequent usage. Outside sources under consideration include the use of rainwater, saltwater and main water, even though the quality of this last source may not be up to drinking standard, as mentioned earlier.

It is common knowledge that the different household uses of water have different quality requirements, thus creating opportunities to take water from different sources, depending on the quality needed for each specific use. Three distribution lines, of different qualities of water, have been considered.

The drinking quality line will be directed exclusively to the kitchen and the bathroom wash basins.

A second water line, which should be at least of bathing quality, will supply the bath tub, shower, bidet and the dish and clothes washing machines, and will mainly be supplied by an accumulation tank (AT), which will contain basicly rainwater. This line could also be supplied by the public supply system, during dry periods, if the rainwater flows are insufficient.

The capacity of the accumulation tank (AT) for consumption water will be established on the basis of the flows involved and the respective retention times. The excess from this tank will be fed to an accumulation tank for irrigation water (IT).

Finally, a third water line, saltwater line, will exclusively supply the toilet water closet tanks, which will be appropriately designed to work with saline water. This will be stored in a specific saltwater accumulation tank (ST). Urinals will be designed to work without water (using a liquid seal).

With respect to the water treatment systems (WT) envisaged, $WT_D$ treatment will only be applicable when the public network does not supply safe drinking water, and it will be a physical-chemical treatment, with disinfection, to make it safe to drink.

$WT_B$ treatment could also be a physical-chemical treatment followed by disinfection, aimed at making sure the water for general use is at least up to bathing water quality.

In terms of wastewater, several treatment systems will be considered in this project (WWT). They will have different goals, but the overall intention is to achieve sufficient quality for it to be used in the garden, or to guarantee the wastewater quality needed for discharge into the receiving environment. Treatments for the control of wastewater storage conditions may also be considered.

In terms of untreated salt wastewater (black water), this will first undergo a preliminary solid/liquid separation treatment ($WWT_P$), after which the liquid phase will be adequately treated ($WWT_L$) for final disposal (salt water areas or salt wetland areas). In order to facilitate this treatment it is also possible to add effluents from the water for general purposes line.

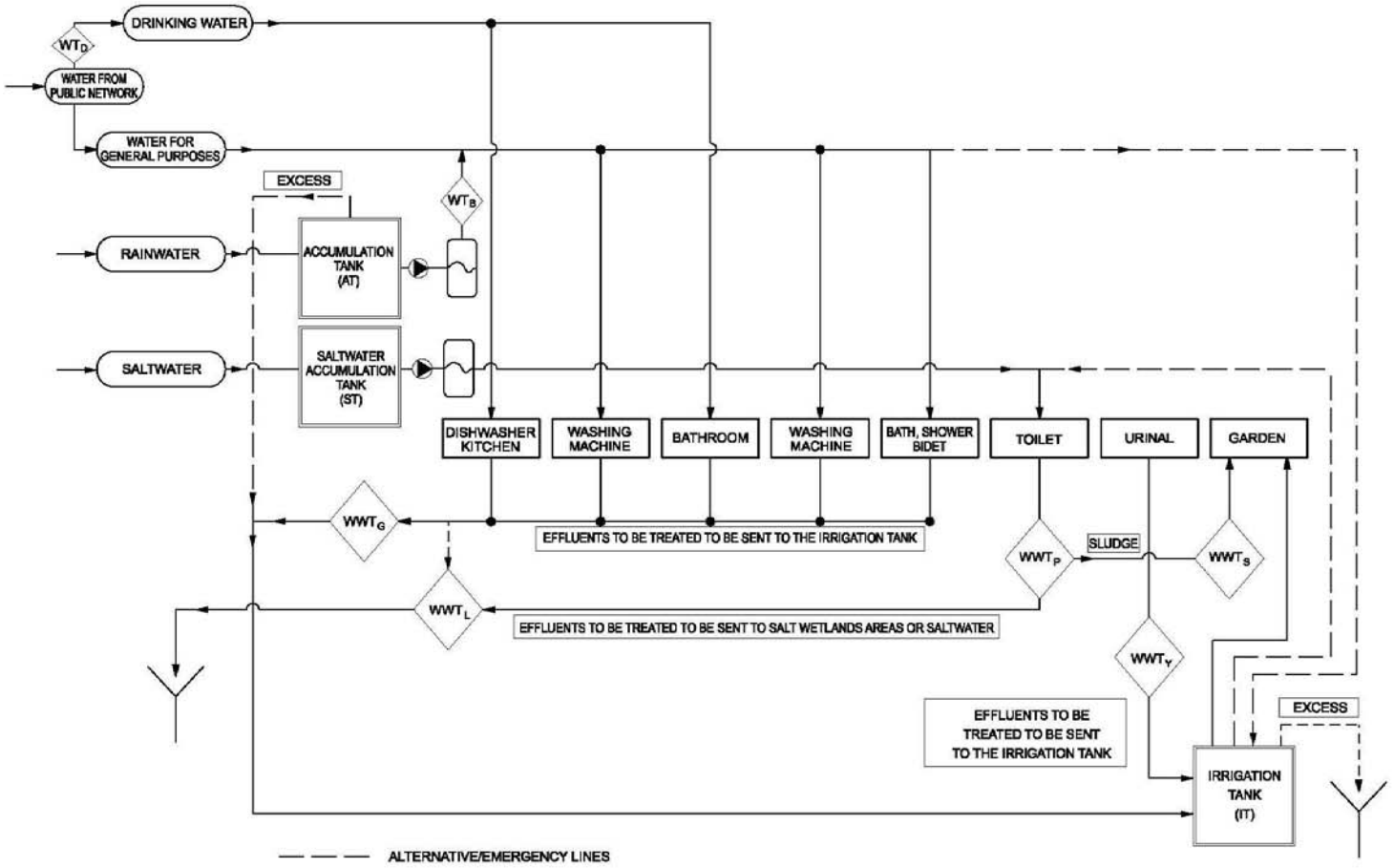


Figure 3 – Scheme of principles

The solid/liquid separation may be achieved using water closets available on the European market, which already enable this separation directly.

The possibility of subjecting the solid phase will be subjected to further treatment ($WWT_S$), to enable the potencial use of the sludge for fertilizing purposes in gardens, is currently being studied.

In terms of grey water, this will first be submitted to a treatment ($WWT_G$), essentially to break down the detergents and fats, after which it will be stored in the irrigation tank (IT). A subsequent phase of this project will then check for the feasibility of a specific treatment of grey water, to enable its use in the water general pruposes line.

The urinal effluents (yellow waters) will undergo adequate treatment referred to as $WWT_Y$.

After treatment, these effluents are also piped to the irrigation water tank (IT). The excess from this tank is discharged into the mains sewerage system. If there is a water shortage in this tank, supply from the general services line may be considered. This situation is not anticipated, however, since the irrigation and gardening subprojects of the “House of the Future” are also looking at the House’s grounds from the point of view of rationalizing water use and minimizing its consumption.

To sum up, the treatment systems will include several processes, which correspond to treatment stages with distinct ends in view, starting with the removal of solids and other insoluble matter, continuing with the removal of biodegradable matter and then proceeding to the removal of microbiological and chemical contaminants. The re-use of solid by-products of the water treatment will also be considered.

## 4. Conclusions

Besides developing various solutions for the future that are linked to increasing ease and flexibility of usages, the Water Supply and Drainage project of the University of Aveiro’s House of the Future also sets out to provide an opportunity to study the possibility of optimizing the water cycle in houses, in local conditions, within a framework of sustainable building.

With this in mind, the studies currently in progress are not only examining a number of measures for cutting consumption, but also the possibility of re-using water, and of using rainwater and non-desalinated saltwater. Such practices would significantly reduce consumption from the mains supply.

When it comes to wastewater treatment systems, several innovative aspects currently under analysis should be noted. These include, for example, specific solutions that allow the collection of the resulting treated wastewater and sludge in a facility close to the house, guaranteeing that environmental quality is maintained, with the development of solutions that will make use of the wastewater and sludge, bearing in mind the particular needs, spatial and temporal, in areas with sundry plant cover, like wetlands, gardens and vegetable plots.

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