DELIVERABLE D 8.2:

Report on the scenario analysis

The research leading to these results has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) under grant agreement nº 619116

Deliverable D 8.2: Report on the scenario analysis

Project acronym: demEAUmed

Project full title: Demonstrating integrated innovative technologies for an optimal and safe closed water cycle in Mediterranean tourist facilities

Grant agreement no.: 619116

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Dissemination Level		
PU	Public	✓
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including Commission Services)	
CO	Confidential, only for members of the consortium (including Commission Services)	

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List of acronyms and abbreviations

CA: Consortium Agreement

DM: Dissemination Manager

DoW: Description of Work

EC: European Commission

EM: Exploitation Manager

GA: Grant Agreement

IPR: Intellectual property rights

SC: Steering Committee

S&T Manager: Scientific and Technical Manager

WP: Work Package

WPLs: Work Package Leaders

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1. Project Overview

demEAUmed (Demonstrating integrated innovative technologies for an optimal and safe closed water cycle in Mediterranean tourist facilities) is a European project co-funded by the European Union under the 7th Framework Program within ENV-2013-WATER-INNO-DEMO-1 with a budget of 5,831,908 M € over 42 months, and started officially on January 1st, 2014. The aim of demEAUmed project is the involvement of industry representatives, stakeholders, policy-makers and diverse technical and scientific experts in demonstrating and promoting innovative technologies, for an optimal and safe closed water cycle in Euro-Mediterranean tourist facilities, leading to their eventual market uptake.

The demEAUmed consortium is led by LEITAT, scientifically coordinated by ICRA and is composed of 15 members from different fields - business, research, technology, hotel communities and public agencies and organizations - from seven European countries: Spain, Germany, The Netherlands, Austria, Italy, France and Belgium.

demEAUmed will face two key challenges: the importance of the tourism economy and water scarcity characteristic of the area. It will be a critical platform for promoting the use of sustainable and innovative technologies in other Euro-Mediterranean tourist facilities in light of also the global tourism market. The project will design a dissemination plan analyzing critical stakeholders/customers to adequately transfer demEAUmed results. Creation of new market opportunities to European industry and SMEs will also be addressed. A representative resort placed in Catalonia, Spain, is considered as a DEMO site, where a representative part of all inlet and outlet waters will be characterized, treated with proper innovative technologies, and reused to reduce the carbon footprint of water management in an integrated approach at demonstration level.

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2. Objectives of the Deliverable

The main objective of this deliverable is to document the development of the decision support system (DSS) for determining the environmental, economic, and social impacts of the installation/incorporation of water-saving and/or water-reuse technologies and practices in hotels. The creation of the DSS is achieved by the following objectives:

- **Determine the organization/architecture of the DSS** – The DSS consists of several components that integrate a water cycle model, technology modules, water quality data, and environmental/economic/social impact data.
- **Development a water cycle model** – The central part of the DSS is a water cycle model that simulates the flows and water quality of a hotel given its characteristics (i.e. number of guests, number of diners, hotel appliance characteristics).
- **Integrate water reuse technology modules** – The water cycle model also uses water reuse treatment technology data from the partners to simulate water reuse in the hotel.
- **Integration of environmental/economic/social impacts** – Results of the DSS are based on impact data related to the technologies used in the hotel water management simulations.

This document is aimed towards the consortium partners of the demEAUmed project, which will provide information on the life cycle as well as their technologies operation for their subsequent incorporation in the DSS. In addition, this tool can also be used by treatment technology companies, hotels, as well as other stakeholders related to the tourism industry. This document will begin with a summary of the existing research on water use in hotels, as well as existing water cycle models, followed by the development of a water cycle model using a program called UWOT, and finally the development of a web-based decision support system (DSS).

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3. Background Preparation

3.1. Literature Review

In order to design a DSS for hotels with respect to water use, background information has to be obtained on the relationship between hotels and water. Therefore, existing peer-reviewed literature was read to better understand this relationship.

Using the database Engineering Village (www.engineeringvillage.com), search terms such as “hotel water use” and “hotel water consumption” were used to look for peer-reviewed journal articles. This search resulted in 9 peer-reviewed articles. Of these articles, 5 focus mainly on water consumption while the other 4 look at water and energy savings. Studies ranged in location including: Hong Kong; Zaragoza, Spain; Shenzhen, China; Oahu, Hawaii, USA; Mallorca, Spain; and Barbados. Studies also considered a range of hotel sizes.

Water consumption-focused studies mainly had the objectives of determining the important hotel characteristics that determine water use and to develop models that can be used to predict water use. The earliest peer-reviewed study analyzed the water use habits of 17 hotels in Hong Kong ranging from 3 to 5 stars (Deng & Burnett, 2002). Results showed that factors such as the number of guests, “food covers” and in-house laundry service were responsible for a large amount of water consumption. In fact, for hotels with an in-house laundry service, this service was responsible for more than half of the hotel´s water consumption. In hotels with outsourced laundry services, kitchens were responsible for 55% of the total hotel water consumption, followed by rooms which were responsible for 45%. A similar study, with different explanatory factors, was conducted in Barbados (Charara, Cashman, Bonnell, & Gehr, 2011). In this case, the number of guests normalized by the nights stayed was shown to be the most important factor in estimating water consumption. For higher level hotels, the number of employees is also a significant factor.

Other consumption-based studies resulted in the development of models for hotel water use predictions. Gopalakrishnan & Cox (2003) used data obtained from hotels in Oahu, Hawaii, USA to create a linear regression model that would estimate water use based on hotel characteristics. The numbers of rooms, pools, and restaurants as well as the presence of a golf course were all significant factors in the resultant equation. Another model was made using data from hotels in Mallorca, Spain, yielding similar results to those found in the aforementioned study. For instance, the number of hotel rooms and pools also had a significant influence on water use in this study. Other factors such as average annual occupancy rate, the months the hotel is open, and the management system (chain affiliation) also significantly contribute to overall water use (Deyà Tortella & Tirado, 2011). Blokker (2009) used a different modelling methodology by determining the functional rooms or rooms where water is being used. Based on this model, hotel rooms use the most water followed by meeting rooms, the kitchen, and cleaning.

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Water savings-based studies mainly quantified the degree to which water-saving technologies can minimize water usage in a hotel. For instance, Gatt & Schranz (2015) documented the results of the replacement of water using devices with their more efficient counterparts. Retrofits included aerators, showers, and toilet cistern volume displacers, which were all responsible for a 48% drop in total hotel water consumption. Barberán, Egea, Gracia-de-Rentería, & Salvador (2013) estimated the water and economic savings of retrofitting a hotel in Zaragoza via a linear regression model that took into account hotel characteristics including number of guests, event attendance, meal attendees, retrofits and season. Retrofits included tap replacement, aerators, discs added to shower heads, new pre-wash shower heads, and devices that control water flow to dishwashers. This retrofit was responsible for a water usage savings of about 21%. Styles, Schoenberger, & Galvez-Martos (2015) analyzed the effects of retrofits to different types of hotels or lodging by developing a model to estimate water use for a standard 100-room hotel and campsite with 80 spaces with and without water-saving retrofits. For a 100-room hotel, implementation of water-saving technologies could reduce potable water use about 75%. Meanwhile for a campsite, water use can be reduced up to 70%. Also, depending on the technology added, water savings may also translate to energy savings. This was the case with a study conducted in Shenzen, China that examined the feasibility of the installation of a solar water heating system in a hotel. Results showed that a solar water heating system could support most of the rooms in a 400-room hotel with a 5-star rating (Chan, Li, Mak, & Liu, 2013).

3.2. Review of Water Cycle Models

3.2.1. Models Reviewed

Existing models that simulate water management were reviewed for possible incorporation in the DSS. The advantage being that use of these models would save time in creating another water cycle model for the DSS. A search was carried out and about nine models were reviewed. These models include: Dynamic Metabolism Modelling (DMM), DUWSim, City Water Balance (CWB), UVQ, Urban Water Optioneering Tool (UWOT), WESTforIndustry, Watermet[2], Urban Development, SIMBA. Models were evaluated based on the criteria of: Freeware, Programming Language, Dynamic or Steady State, Hotel Scale, Scale, Water Flows and Quality, State Variables, Technologies, Urban Water System Elements, Life Cycle Assessment, Energy Usage, Ability to be modified. A comparison of the models is shown in Table 1. The most important criteria were: the ability to model the building scale, the ability to add new technologies, and the ability to determine environmental and cost impacts.

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Table 1: Comparison of the existing water cycle models

Model Name	UWOT	WESTforINDUSTRY	DUWSim	SWITCH	DMM	WaterMet²	UVQ	SIMBA
Freeware	✔	✔	✔		✔	✔	✔	
Programming Language	.NET	Modelica	C#/Excel	Unknown	Excel	C#		C#
Dynamic	✔		✔		✔	✔		
Hotel Scale(s)	✔	✔				✔	✔	✔
Community/City Scale	✔	✔	✔	✔	✔	✔	✔	✔
Water Flows	✔	✔	✔	✔		✔		✔
State Variables		✔		✔		✔	✔	✔
Technologies	✔	✔			✔	✔	✔	✔
UWS Elements	✔	✔	✔	✔	✔	✔	✔	✔
LCA	✔			✔	✔	✔		
Energy Usage	✔		✔	✔		✔		
Modify?	✔	✔	✔	✔	✔	✔	Maybe	✔

3.2.2. Building Scale Modelling Capacity

As the system modelled is a hotel, the water cycle modelling software considered has to at least be able to feasibly simulate the flows, technologies, and the specific water quality within a hotel, even though the objective would be to include also cost, energy and environmental impacts. While the lowest scale for most of the reviewed software is either the building or the city block, the main purpose of much of the software is for a more neighborhood or city-scale analysis of water management scenarios. In DUWSim, the land use cell is an area of about 4ha that may have more than one building on it. Yet, while land use cell-level water balance calculations are detailed to the point that the user can actually simulate different on-site water management alternatives, this software is mainly used for larger-scale water management analyses as it relies on GIS maps (Willuweit & O'Sullivan, 2013). The case is similar for SWITCH, in which at the building scale, the user can assign demand profiles, contaminant loadings, and the amount of pervious/impervious area. However, the lack of detail assigned to this basic unit shows that this water cycle model is more appropriate for community or neighborhood scale analyses or higher (Mackay & Last, 2010).

Conversely, UWOT can model water management at the building scale. In fact, depending on the building, there are two methods that can be used. The user can either model only one building by designating the "appliances" in the building, its occupancy, and its onsite water management technologies, or model the building as a neighborhood (such as a hotel), modelling each room as a separate building. A similar setup can also be applied to WaterMet² by modelling large buildings as sub-catchments.

The most ideal models for water management of individual buildings are WESTforINDUSTRY and SIMBA. WESTforINDUSTRY and SIMBA rely on the user´s setting up flowcharts in which the arrows and lines represent flows and boxes represent treatment processes or demands. As a result, different configurations of onsite water management in buildings can be more accurately modelled. However, these programs mainly focus on wastewater treatment. Therefore, some improvisation would be needed to adapt this software to all aspects of water management. Also, certain water management

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alternatives such as rainwater harvesting and alternative stormwater management may be a challenge to simulate with these programs.

3.2.3. Addition of New Technologies

Almost all models with the exception of DUWSim have the ability to incorporate new technologies. In the case of SIMBA and WESTforINDUSTRY, new models can be added to the model libraries by calculating pollutant removal and cost equations for new model blocks. UWOT is also able to incorporate new technologies via modification of a connected spreadsheet file. For WaterMet^2, specific treatment technologies cannot be added as water and wastewater treatment are simulated at the plant level. Still, alternative treatment facilities can be simulated by specifying the associated chemicals, energy use, as well as the contaminant removal rates. CWB and UVQ can also incorporate new technologies; however, the degree of detail to which they can be simulated is unknown.

3.2.4. Energy, Cost, and Other Impacts

Some of the reviewed water cycle models include some type of built-in peripheral analysis (i.e. cost, environmental impacts, energy). WaterMet^2 actually calculates the "metabolism" of a water management system by letting the user define the embodied energy factors for all aspects of the system. DUWSiM and DMM use sustainability indicators to determine the environmental impacts associated with the scenarios (Venkatesh et al., 2014; Willuweit & O'Sullivan, 2013). Both models are connected to spreadsheets with factors to calculate sustainability analyses or life cycle assessments. Both include life cycle costing. Spreadsheets are also used for life cycle costing and energy analyses for CWB (Mackay & Last, 2010). Included in the results of UWOT is an energy analysis; however this may most likely be related to the electricity use associated with water use.

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4. Development of the Water Cycle Model

4.1. UWOT

UWOT is a .NET-based software that was developed by the University of Exeter for the purpose of modelling water management at different spatial and time scales. Water management can be modelled at time steps as small as 15 minutes. Water demand is driven by water-using appliances, building or room occupancy, and the number of units. Residential and non-residential buildings can be modelled. The software even has built-in daily water consumption patterns. Climate and weather data can also be added to the simulations. Water management simulations can be carried out from the building scale to the city scale. In addition, decentralized and centralized water, wastewater, greywater, and rainwater management/treatment technologies can be incorporated. Water quality is also taken into account, but it is modelled as categories (i.e. potable water, greywater, greenwater, wastewater) as opposed to concentrations of contaminants. An application of this program to a site in the UK has been published by Makropoulos, Natsis, Liu, Mittas, & Butler (2008).

4.1.1. Case Study

Based on the important criteria outlined in Section 3.2, UWOT was the first choice for integration as the water cycle model within the DSS. A case study using UWOT was carried out to estimate the effect of the installation of Hotel Samba's greywater reuse system on potable water use and energy use. The water cycle modelling software, UWOT, due to its abilities to model an individual building and incorporate water reuse technology, has been applied.

4.1.2. Information Sources

Information was provided by the hotel including: number of hotel rooms, number of bathrooms, other services, and the size of the hotel. In addition to the hotel rooms were the service rooms or service areas located inside the hotel. Each hotel room had the following water-using devices (WUDs): shower, sink, toilet and bath. Hotel-wide services included: restaurant, bar, conference room, administration, pool, laundry, and reception. Each of these places has at least a WUD.

4.1.3. Scenarios Modeled

There are two scenarios that are modelled in this case study. The first one, referred to as business as usual (BAU), refers to the hotel without the water reuse technology. In this scenario, only potable water is used for all WUDs. The second scenario will be referred to as the water reuse scenario in which greywater from hotel rooms is sent to a greywater tank, gridded, disinfected and then sent back to the hotel room´s toilets.

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4.1.4. Results

A comparison between the potable water use percentages by water use device is shown in Figure 1. Since treated greywater is used for toilet flushing, the 25% of potable water that is used for this purpose in the BAU scenario is halved in the water reuse scenario. This shows that treated greywater can actually impact a significant use of potable water.

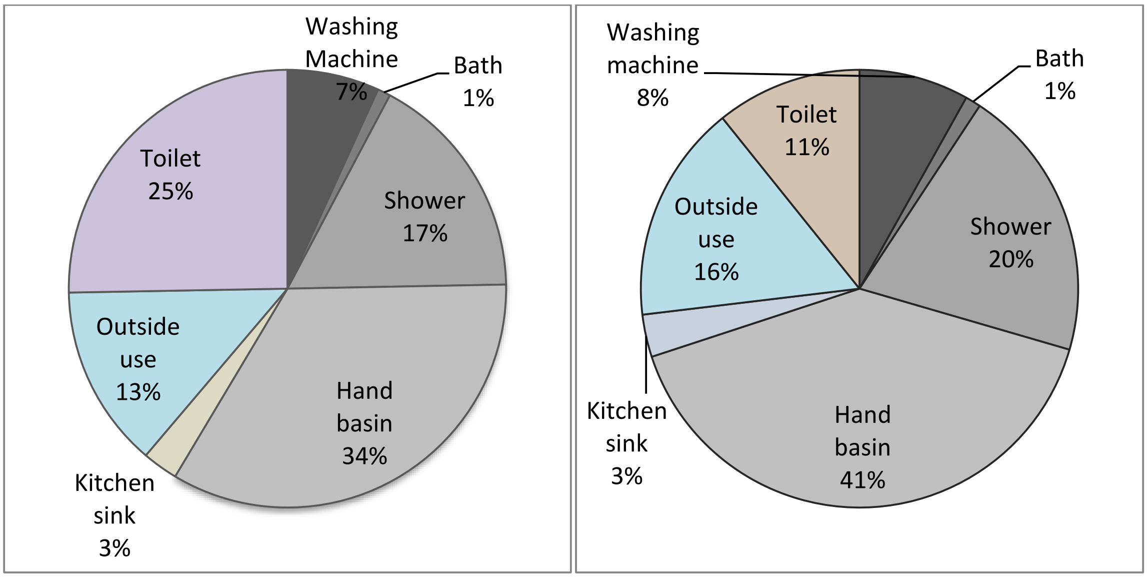

Figure 1: Percentage potable water use by water using device for the BAU (right) and Water Reuse (left) scenarios

Figure 2 illustrates the comparison in terms of water, wastewater, and energy uses between the two scenarios. As expected, potable water and wastewater values decrease about 16% and 19%, respectively, when greywater is reused. In the BAU scenario, the used shower and sink water would be directly sent to the wastewater treatment plant. Therefore, the incorporation of greywater reuse technology actually moves the greywater to a storage tank for its subsequent treatment, thus resulting in a decrease in wastewater production. Conversely, energy use actually increases about 6% in the water reuse scenario. This is mainly due to the installation of a new onsite technology that uses energy for pumping and mixing.

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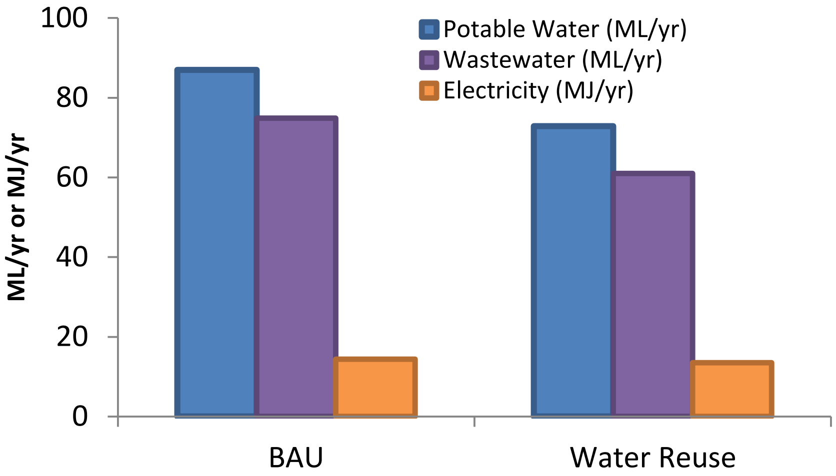

Figure 2: Comparison of potable water, wastewater, and energy uses by scenario

4.1.5. Discussion

A 16% savings in potable water is significant for a hotel. However, currently, there are no real economic or energy incentives to carry out this water savings in the hotel industry. For example, water costs are only responsible for about 4% of total hotel expenses on average in Mallorca (Deyà Tortella & Tirado, 2011). In the case of this hotel, water is only about 1.4% of the total maintenance cost. Also, addition of a new technology would require not only additional cost but could even consume more energy. Nevertheless, while the energy bill for hotel Samba is about 2.6 times the water bill, this is still relatively small when compared to the rest of the hotel expenses (3.6% of the total budget). Nonetheless, it has to be remarked at this point that also environmental and other benefits should be internalized to perform a more fair analysis.

4.2. Information Gathering

4.2.1. Simulating Flows

In January 2016, development began on the program SambaNet. However, first the pertinent information had to be gathered in order to test this water cycle model. Hotel Samba provided a blueprint of the hotel. A questionnaire submitted to the hotel to obtain information on the WUDs as well as the number of employees and different room classifications at Hotel Samba (Table 2-4). The hotel was able to provide most of the information specified on the questionnaires.

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Table 2: Water Use Device Data Questionnaire

WATER USE DEVICE DATA			
Characteristic	**Amount**	**Unit**	**Comment**
Shower	9	L/minute	
Hand basin (Room)	8	L/minute	At medium speed used to wash hands and/or brush teeth
Kitchen Sink		L/minute	A medium speed used to wash or rinse dishes and cookware
Bath	0.2	m^3 Volume	Length/Width/Height of the bathtub as well as volume
		% basin filled	Estimation of % filled when taking a bath
Toilet	6	L/flush	
Washing machine	6	L/load	
		Loads/day	
		Loads/room	

Table 3: Employee data questionnaire

Characteristic	Amount	Unit	Comment
All Staff	80	Employees	All staff including cleaning and laundry
Administrative Staff	8	Employees	Number of people who work in the administration office

Table 4: Room Characteristic Questionnaire

ROOM CHARACTERISTICS				
Room Type	**Max Quantity**	**Number of Beds**	**Shower/Bath**	**Comments**
Suite	2	1	1	jacuzzi
Double	351	4	1	
Individual	44	1	1	
Familiar 1	16	4	1	
Familiar 2	28	6	1	

In January 2016, ADASA installed and began to run Samba Hotel's monitoring system (WP5 activity of demEAUmed). At the time, real time data could be collected on flows. Data from this monitoring system was collected over a 3-week period. Simultaneously, Hotel Samba provided data on the number of guests and diners recorded for each day during this period. Therefore, hotel guest data, combined with the flow data as well as the WUD data from the aforementioned survey was used to ultimately determine the relationships between the number of hotel guests and/or diners and the amount of water used by each WUD (i.e. toilets, sink, washing machine, etc.). For instance, toilets at the hotel use 6 L per flush (Q_{flush}). Toilet flow data collected from the SCADA system for a certain day, d, is summed to a value Q_d. A certain number of guests (N) stayed at the hotel during this same day. Therefore, the toilet use frequency can be calculated by using (1).

$$F = \frac{Q_d}{Q_{flush} N} \qquad \textbf{(1)}$$

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Where F refers to the average number of flushes per guest per day. Similar calculations were done for almost every WUD based on the flows taken from the SCADA system, the data taken from the questionnaire, as well as basic assumptions about certain water using habits.

4.2.2. Simulating water quality

Water quality data from the campaign carried out for WP3 (Water Cycle Diagnose in Samba DEMO site) was used to determine the loadings of designated pollutants. This sampling campaign was carried out in June and November of 2014. During this campaign, flows from most of the WUDs were sampled for contaminants and water quality parameters. The contaminants used in the DSS were: total suspended solids (TSS), phosphates ($P\text{-}PO_4$), Sulfates ($S\text{-}SO_4$), total organic carbon (TOC), chemical oxygen demand (COD), biochemical oxygen demand (BOD), total nitrogen (TN) and three micropollutants: caffeine, carbamazepine, and diclofenac.

Assuming a constant concentration for the entire day, the loading per "use" of each WUD was able to be estimated. For instance, knowing that a flow of Q_d goes through the toilet for a whole day, the total daily loading of a contaminant x (L_x) can be calculated using equation (2).

$$L_X = Q_D C_X \quad \textbf{(2)}$$

Where C_x is the concentration of contaminant x in the WUD stream.

Again, this or a similar method was applied to the flows associated with each WUD in the hotel. Once the daily loading was calculated, the loading per WUD use (L_U) could be estimated using equation (3).

$$L_U = \frac{L_X}{U} \quad \textbf{(3)}$$

where U is the number of uses of the WUD being analyzed.

4.3. SambaNet MATLAB Based Model

While UWOT could be adapted to hotels, for the purposes of this the DSS a program more specific to hotels is needed. Since there is no existing program that focuses on the water management system of hotels, it was decided that a water cycle model would be developed. The basic concept of this model would be to simulate water management of a wide array of hotels. The user would specify the hotel characteristics, the numbers of guests and diners, and the reuse technologies and pathways used. The program would then estimate the flows and corresponding water quality based on the data obtained and processed (described in section 4.2). The program would be steady state and user friendly.

4.3.1. Programming Architecture

The basic setup of the MATLAB based model consists of two programs in which one is called on by the other. One program (Sambanet) is responsible for the visual interface in which the user inputs the hotel characteristics, WUDs, and the numbers of guests and diners (Figure 3). The program records the input values and calculates the daily water use of each WUD. Simultaneously, the user also uses a reuse grid to determine reuse connections. This grid communicates with a reuse matrix where numbers larger than zero represent the type of technology used for water reuse treatment.

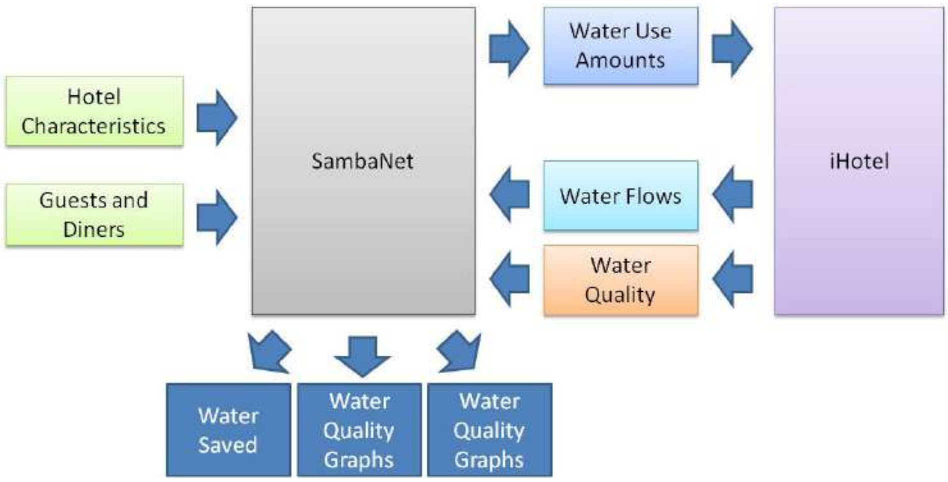

Figure 3: Diagram of the setup of Sambanet

This information calculated as the input for a hotel water management (iHotel) program, organizes the water use values, reuse matrix, and use frequency values into matrices. Using these matrices, the water flows, quality, as well as reuse setup is simulated. More specifically, this model divides the flows into hourly values. At time 0, all water is simulated as coming from the tap. For as long as the user specifies, the system runs on a loop to reach steady state flows and concentrations. The outputs of flows and concentrations are then sent back to the original program for data analysis and visualization.

4.3.2. Program Structure

Two versions of the water cycle model have been programmed using MATLAB. Both of these versions are steady state and only simulate total daily water use.

The first version of the water cycle model uses a graphical user interface (GUI) in which the user specifies the characteristics of each water-using device (WUD) as well as the occupancy rate (Figure 4). A results tab shows the different amounts of potable water, wastewater, greywater, yellow water, and black water produced.

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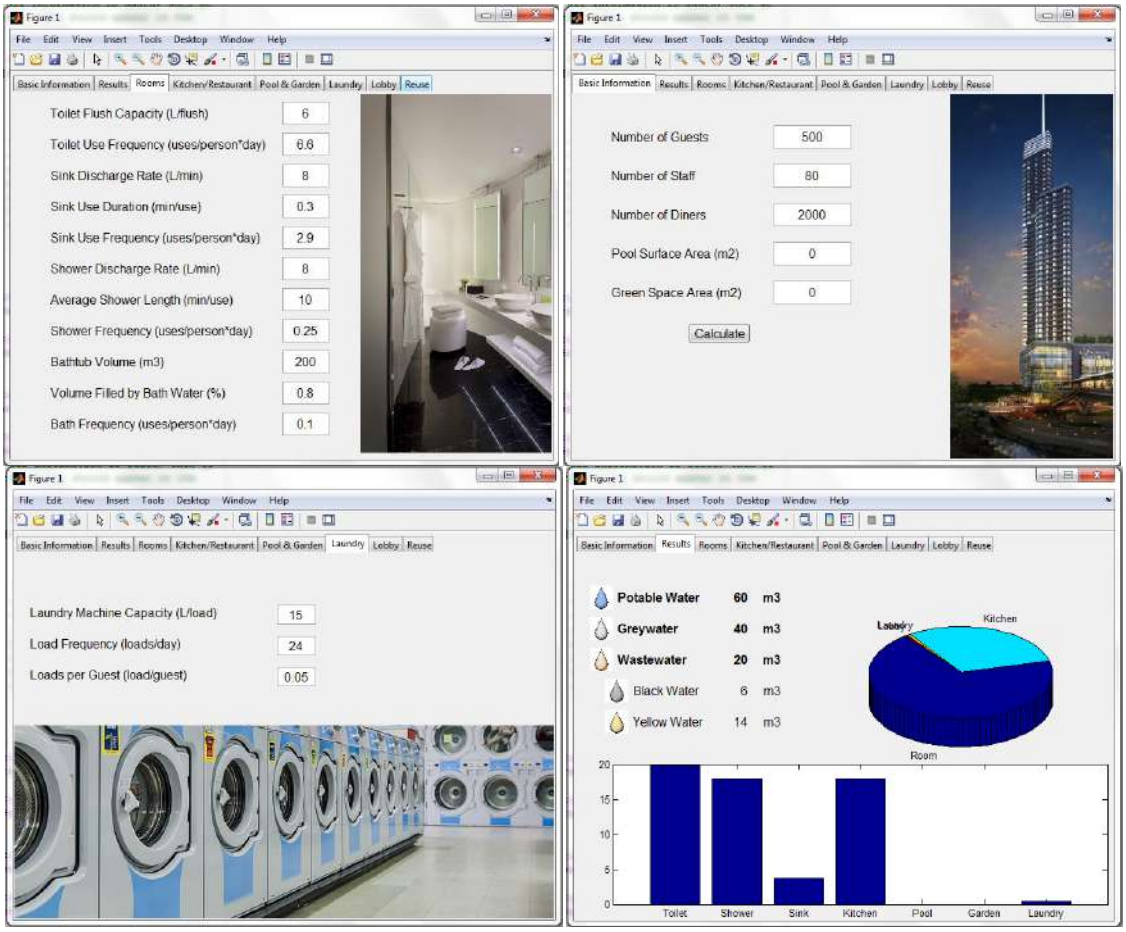

Figure 4: Visual interface of the first version of SambaNet

The second version also uses a GUI (Figure 5-Figure 7). The user specifies the services that are included in the hotel and subsequently the WUDs associated with the chosen services. Based on these services, the user also creates a water reuse table where reuse pathways as well as the technologies for reuse can be specified. The user can also determine the number of guests and diners. Once all the necessary information is input, a results screen appears with the potable water user per day, the amount of water saved/reused, as well as graphs illustrating the potable and reused water flows associated with each WUD and the water qualities associated with each of the flow pathways.

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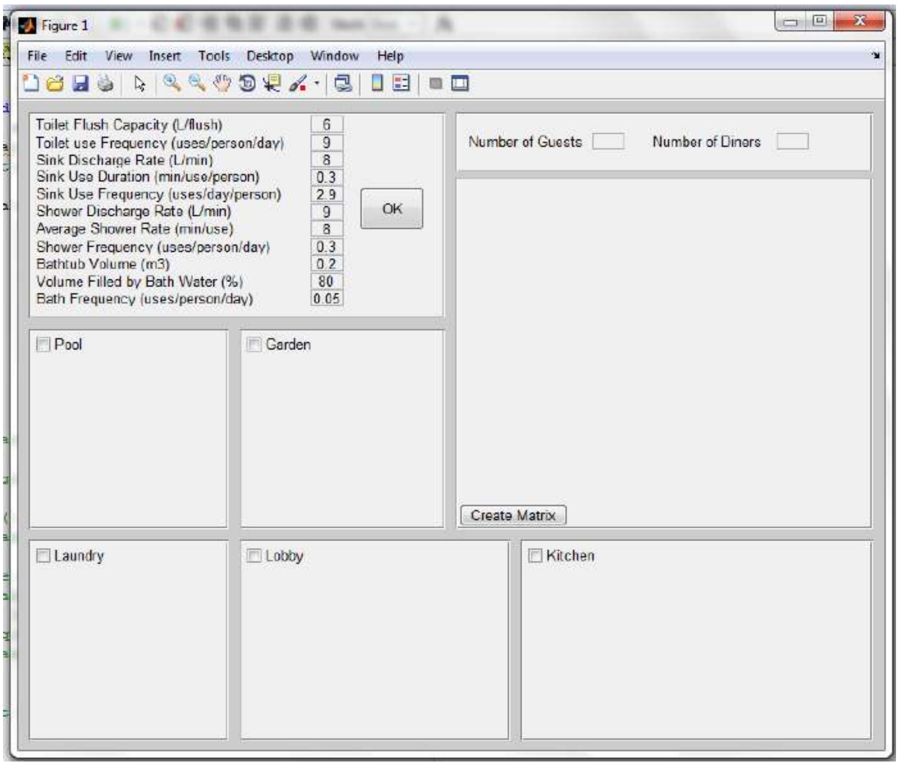

Figure 5: First Screen of the MATLAB version of SambaNET

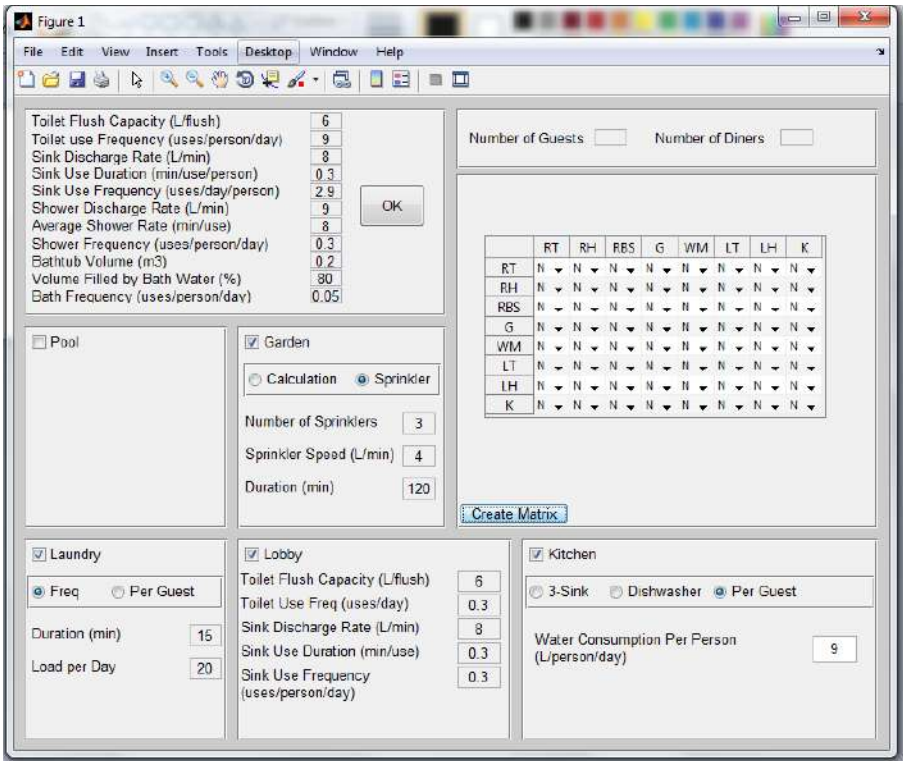

Figure 6: Second screen of the MATLAB version of SambaNet *(*RT- Room toilet, RH – Room Handbasin, RBS – Room Bath/Shower, G – Garden, WM – Washing Machine, LT – Lobby Toilet, LH – Lobby Handbasin, K – Kitchen)*

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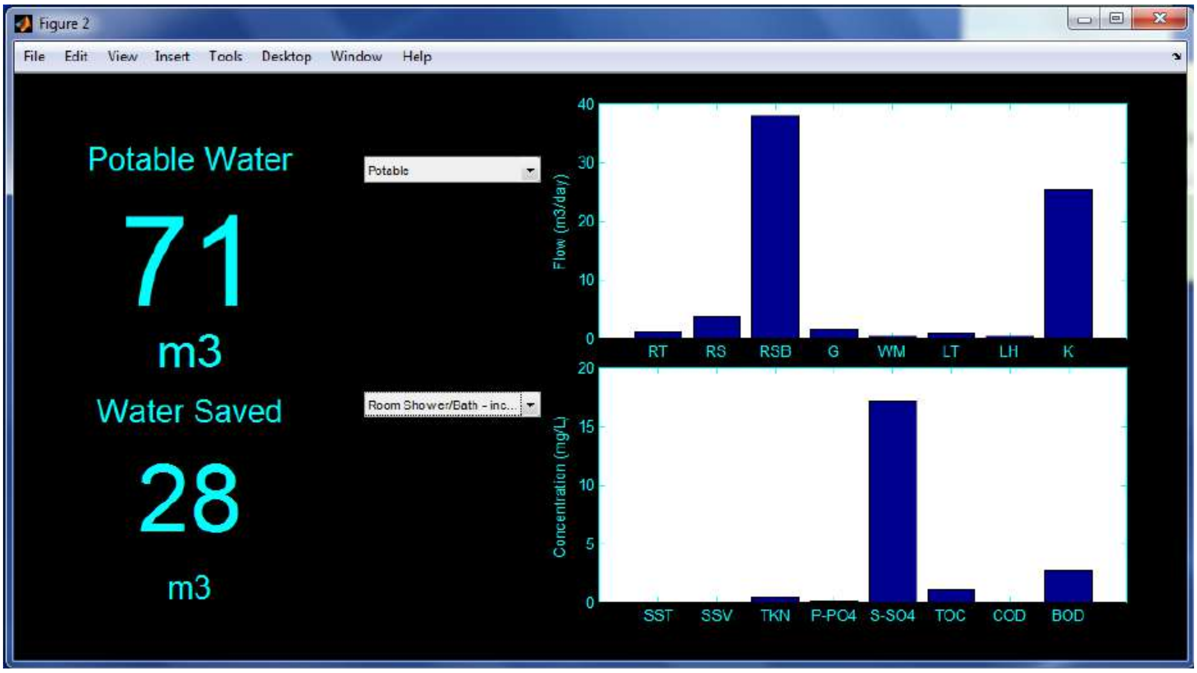

Figure 7: Results screen of the MATLAB version of SambaNET

4.3.3. Limitation of the applied MATLAB model

During the programming of the MATLAB model, one issue was the lack of flexibility in setting up the water reuse matrix. Onsite water reuse systems can be varied. Only a limited range water reuse scenarios can be modeled by this program. For instance, water from one WUD can be treated and reused by one or more WUDs. From that same WUD, the different streams can be treated by the same or different technologies. Nevertheless, the greywater reuse system at Hotel Samba would not be accurately modeled by this program. This reuse system collects water from the room showers and the room sinks in a tank, treats it via chemical treatment, and sends it to the toilet. Therefore, this program does not take into account the mixing of used water from different sources before treatment. Another issue is the inability of the program to create treatment trains from the existing technologies

The main drawback is the use of MATLAB for programming of an application for public. To use MATLAB on another device, it must have MATLAB installed and since this program calls on Excel files, the corresponding spreadsheets must also be on the device. While there is a compiler for MATLAB that can be used for app development, this component would cost extra money.

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SambaNet – Web-Based Java Model

In order to make the water cycle model (and consequently, the decision support system) more accessible to stakeholders, it was decided that the existing water cycle model would be reprogrammed in Java and a web-based program that could be accessed by the public. Instead of programming via matrices, which is characteristic of MATLAB, this web-based model was programmed using object-oriented programming.

4.3.4. Overview of the Web-based model

The web-based model generally follows the same format as the MATLAB one. However, the steps are more clearly defined and the aesthetics of the interface have been improved. Improvements have also been made to the reuse network setup, which addresses some of the limitations associated with the MATLAB approach. The tabs have the following order: Water Use, Create Network, Solve Network, Water Reuse, Solve Water Reuse, Contaminants, and Results.

The first step in designing a hotel water management system via SambaNet is to enter the basic characteristics of the hotel. The user enters the values in the boxes on the left-hand side of the screen (Figure 8). This includes the number of guests and diners as well as the basic characteristics of the WUDs that are in the hotel. For a more streamlined process, there are default values that represent the WUD characteristics at hotel Samba. While the user changes the values in the boxes on the left-hand side, the values on the right-hand side immediately change reflecting the relationship between water use and hotel characteristics. The yellow tabs representing each hotel service can be expanded or collapsed.

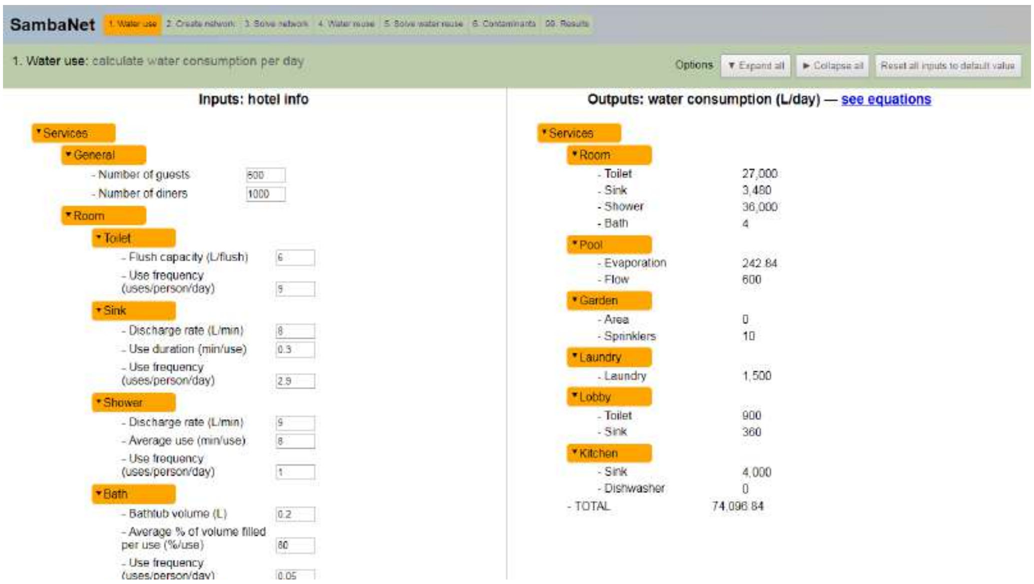

Figure 8: SambaNet Water use interface

Once the hotel characteristics have been set, the user can create the network either manually, or by creating a default network (Figure 9). By pressing the button "Create example network", a network with red arrows appears indicating the direction of flow. The example network is a typical network for a hotel. The user has the option of modifying it once chosen, by creating new connections, creating new tanks, and removing the connections and tanks. The user can also create a new connection specifying the nodes to connect. On the right side of the screen, the user can see a visual representation of the diagram. The user can zoom in or out on the network, move the nodes or even have the graphic occupy the entire screen (or window).

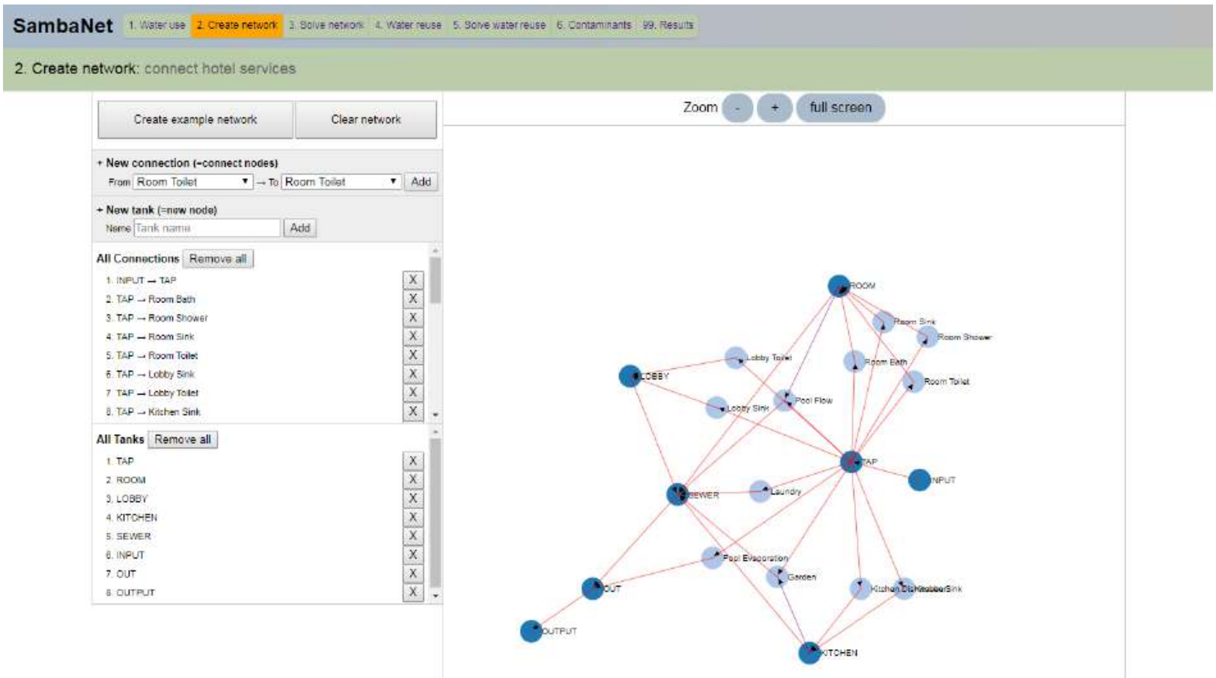

Figure 9: Create network screen for SambaNet

Once the network is created, the user solves its flows based on the setup in the previous screen. By pushing the "Solve network" button, all of the flows within the hotel are calculated with the numerical values on the left side of the screen while a visual representation is on the right side (more thickness of the lines corresponds to a bigger flow) between each node (WUD or tank) (Figure 10). Again, the visual representation can be toggled by zooming in or out as well as expanding to occupy the entire window.

The Water Reuse screen lets the user specify different water reuse applications, allowing to connect nodes and specify the treatment technology between each node as well as the maximum flow for between the nodes (Figure 11). Once created, the reuse connection shows up on the right and left sides of the screen. On the right side of screen the reuse line appears as a purple line.

Once the reuse connections are established, the user can finally calculate the new flows incorporating reuse under the "Solve water reuse" tab (Figure 12). By pressing the "Solve Reuse" button, the flows with water reuse are calculated. Numerical values are on the left side of the screen, while the visual representation is on the right side. The thickness of the line corresponds to the amount of flow between the nodes. A purple line denotes a water reuse line. Similar to the "Solve Network screen", the user can zoom in and out and have the visual representation occupy the entire screen.

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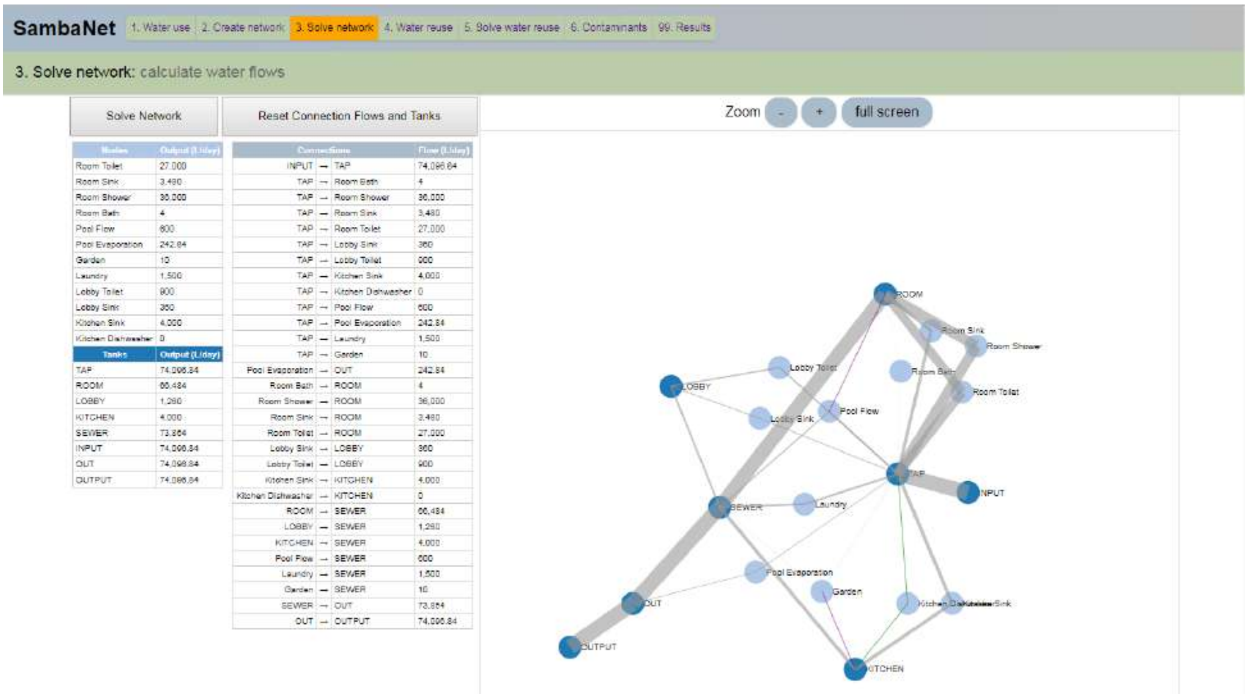

Figure 10: Solve network screen

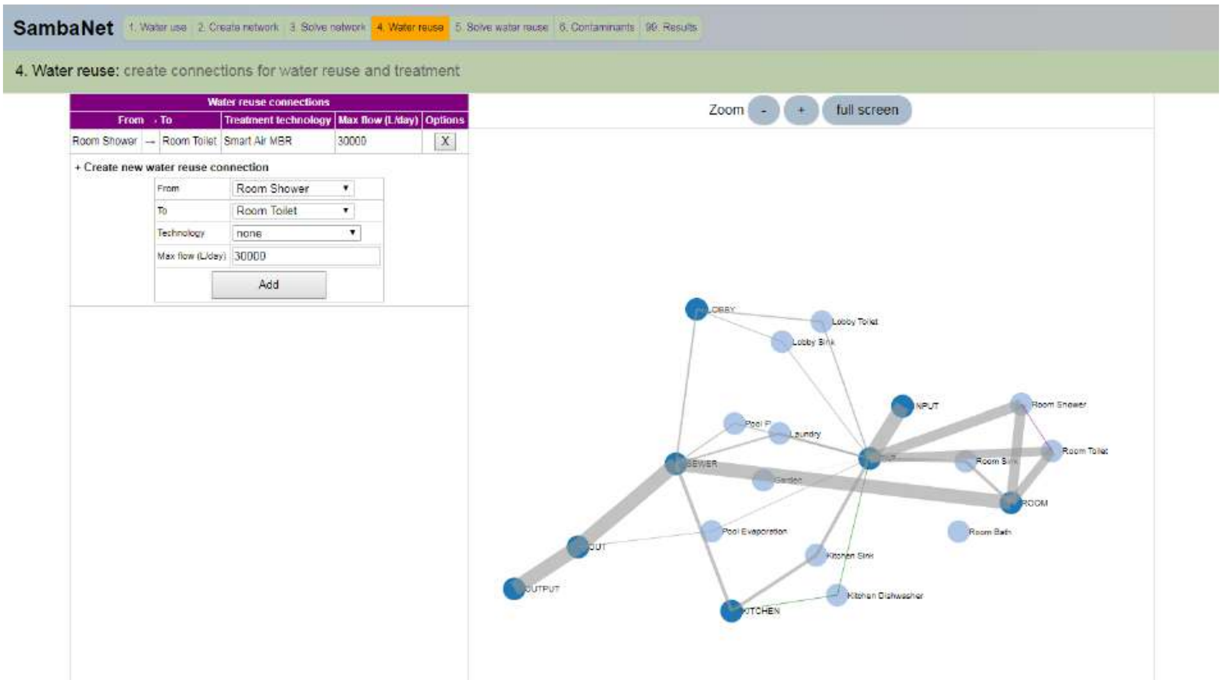

Figure 11: Water reuse screen

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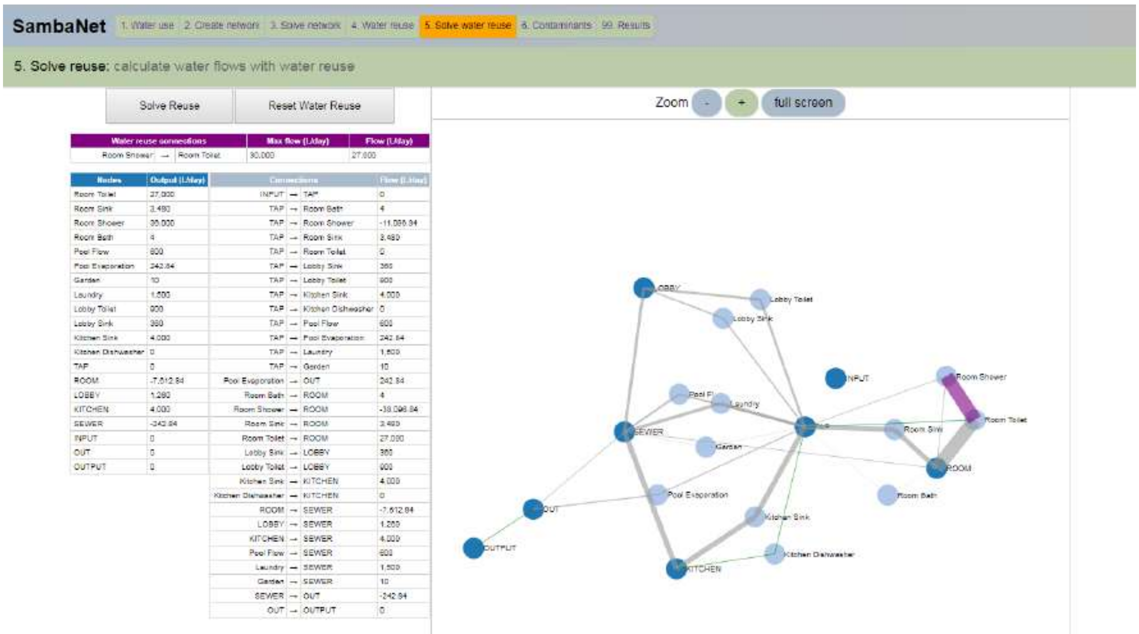

Figure 12: Solve reuse screen

With water reuse now incorporated, the user can then access the water quality of all of the flows within the hotel's water management network (Figure 13). Currently, about 9 contaminants are specified. Values can be represented as concentrations as well as loadings by pressing the "Concentration ↔ Loads" button.

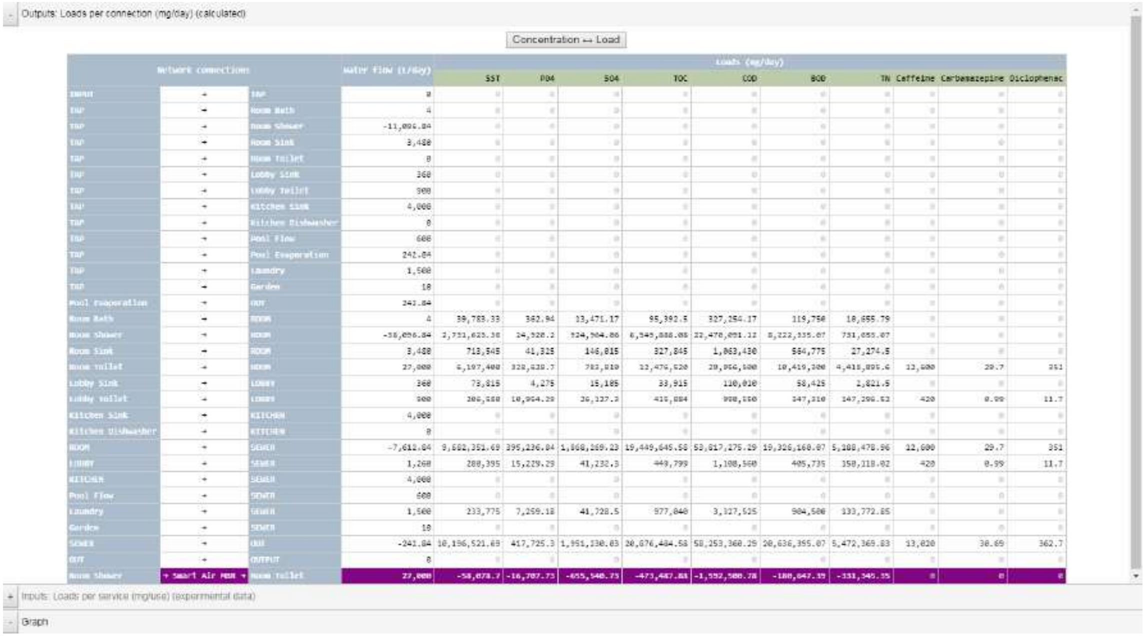

Figure 13: Contaminants screen

Other results can be accessed by clicking on the "Results" tab. This screen currently gives the amount of reuse connections, the maximum amount of water saved and the current amount of water saved (Figure 14).

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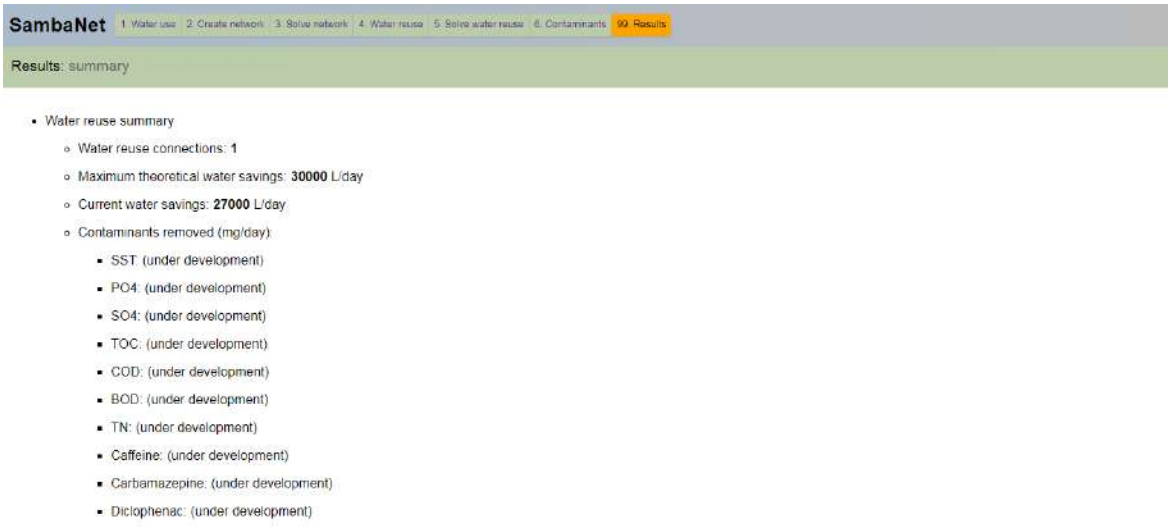

Figure 14: Results screen

5. Integration and Assessment of Water-Reuse Technologies

The ability to integrate new technologies is a necessary feature of the water cycle model in the DSS. This is proposed to be done via "library of models", which consists of algorithms that are able to simulate the operation, cost, energy use, and the environmental impact of water reuse technologies provided by the partners. The integration of this library with a design that takes into account future expansion will help partners and stakeholders better understand the economic, social and environmental implications of integrating their technologies into a hotel´s water management system.

5.1. Integration of water reuse technologies in the water cycle model

During the water reuse network setup stage, the user can specify the water reuse technology to treat the used water. These technologies are incorporated via a table that includes the average removal rates for each of the contaminants designated within the model. Therefore water, being treated with a technology with a removal rate r, with a contaminant concentration C_x will have an effluent concentration C_{xe}.

$$C_{Xe} = (1 - r)C_X \tag{1}$$

Removal rates were provided by some of the partners. Currently, the removal rates of 4 demEAUmed technologies were provided and incorporated into the existing model (Figure 15).

Figure 15: Choose technology screen

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5.2. Assessment of Water Reuse Technologies

While improvements in water management can end up saving water (and money for those who implement them), the burden may be shifted to the environment as onsite reuse systems use extra electricity and chemicals, which may not be compensated by the impacts caused by the existing water management system. Therefore, life cycle assessments and life cycle costing analysis was done for each technology by LEITAT (WP7) on environmental and socio-economical assessment. Via communication with partners, LEITAT was able to obtain inventories that were subsequently used to carry out LCA and LCC. This environmental impact and cost data was then incorporated into the web-based model so that users will be able to estimate the environmental and cost impacts associated with the installation and use of the water reuse technologies. The results of these analyses were then sent to ICRA and incorporated into the DSS.

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6. Conclusions

6.1. Achieved goals

September 2015 to June 2017 has brought a program that was just a simple idea to a point almost where it can be used by various stakeholders in the tourism industry. During these past 21 months a couple goals have been achieved:

- **A better understanding of the hotel water cycle** – Via literature review, questionnaires to Hotel Samba, sampling campaigns, and use of the monitoring system, more insight was gained on how hotels use water. Results from the literature view show that hotel water use is varied in nature as it depends on the services located at the hotel, the number of stars, and the climate to a degree. Focusing on Hotel Samba, a similar dynamic was seen. The number of guests and diners do affect the amount of water consumption. Based on these relationships, a preliminary estimate could be made of the amount of water that is used based on the number of guests and diners at the hotel during a certain day.
- **A Steady State Water Cycle Model –** Beginning in January 2016, programming began on a steady state water cycle model, using MATLAB. The second version is a Java-based web-based program. The MATLAB version gives the user the opportunity to enter hotel characteristic data and set up the water reuse matrix, even choosing the water use technology. The user can then obtain results including water quality of the different components of the hotel's water management network and the amount of water saved. The web based model has a similar function.

6.2. Future improvements

The web-based model was designed to be continually improved. Possible improvements and suggestions to create a tool that improve water management include:

- **Obtaining more hotel water consumption data** – Each hotel is different with respect to water consumption. While Hotel Samba is the default, it only represents one type of tourism context. Hotels in non-coastal areas, with different star ratings, and of different ages need to be analyzed to determine the guest/diner-water use relationships.
- **Collaboration with an existing software developer –** One way to enhance this tool is to work with a developer that has experience in developing simulation programs. This experience could be helpful in determining the user-friendliness of the program as well as finding out what works and does not in program development.

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