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Research Project Presented to the Course Completion Work Program Related to the Reuse Water Treatment System with IoT

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SUMMARY

Over the past ten years, industry has experienced what is called the fourth industrial revolution, or Industry 4.0, injecting unprecedented intelligence into industrial processes through a series of digital "tools" such as IoT, Machine Learning, Artificial Intelligence, and so on. The volume of data produced by this fully digital and autonomous industry cannot be supported by local network networks, as there is a need for massive traffic and information storage. Hence, an ecosystem to support this demand began to be developed, thus emerging: the Cloud. The cloud is a network of servers connected via the internet, creating a network of nearly infinite size. It only requires the addition of more servers for the network to grow. Several companies operate these servers and sell them as a service. To make visualizing a cloud-connected system easier, this work proposes automating a water treatment system, where the system's inputs and outputs will be connected to an IoT board, which in turn is programmed to "talk" to the internet. Throughout the project, all the electrical, electronic, and mechanical designs of the system are explained in detail, as well as the program written to automate the system and, most importantly, connect it to the cloud. Therefore, anyone interested in designing an IoT system will find excellent support in this final project.

Keywords: Artificial Intelligence. Cloud. Machine Learning

ABSTRACT

Over the past ten years, industry has experienced what is called the fourth industrial revolution, or Industry 4.0, introducing unprecedented intelligence into industrial processes through a series of digital “tools” such as IoT, Machine Learning, Artificial Intelligence, and so on. The volume of data produced by this fully digital and autonomous industry cannot be supported by local network networks, as there is a need for massive traffic and information storage. Hence, an ecosystem to support this demand began to be developed: the Cloud. The cloud is a network of servers connected via the internet, creating a network of nearly infinite sizes. It only requires the addition of more servers to expand the network. Several companies operate these servers and sell them as a service. To facilitate visualization of a cloud-connected system, this project proposes automating a water treatment system. The system's inputs and outputs will be connected to an IoT board, which in turn is programmed to “talk” to the internet. Throughout the project, all the electrical, electronic, and mechanical designs of the system are explained in detail, as well as the program written to automate the system and, most importantly, connect it to the cloud. Therefore, anyone interested in designing an IoT system will find excellent support in this final project.

Keywords: Artificial Intelligence. Cloud. Machine Learning

1. INTRODUCTION

1.1. Project Objective

Drinking water, or fresh water, available in nature, is quite limited, around 97.5% of the planet's total water comes from ocean waters, only 2.5% of the water is fresh, however, only 0.3% is available.

available in lakes and rivers that supply the cities and can be consumed, as shown in Figure 1. Of this restricted percentage, a large portion is polluted, further reducing available reserves.

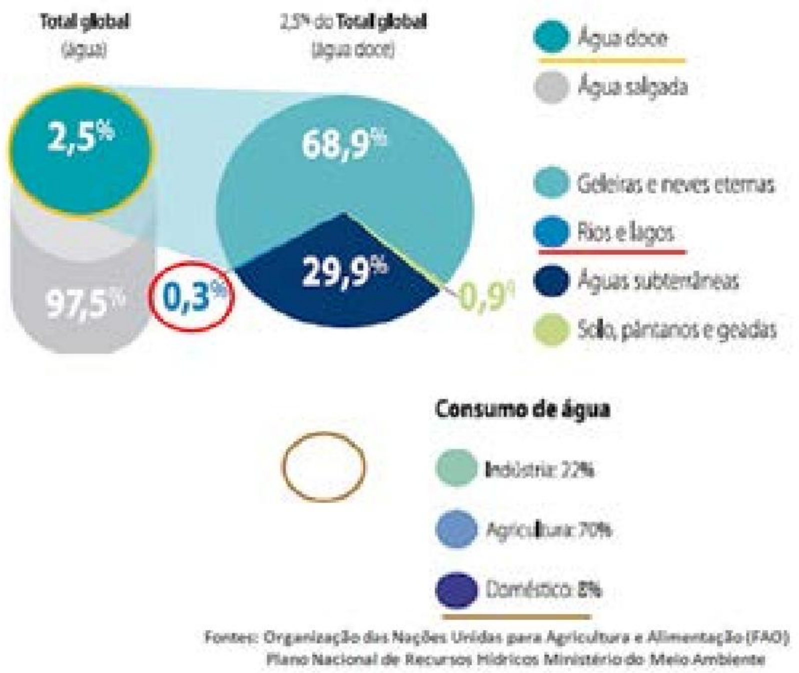

Figure 1: Global drinking water panorama
Source: UNITED NATIONS https://nacoesunidas.org/acao/agua/. Accessed on: 10/07/2019, 15:20.

In this perspective, the UN (United Nations) released a note with a forecast of that by 2050, approximately 45% of the population will not have the minimum amount of water. In the developing world, about 50% of the population consumes polluted water, and across the planet, at least 2.2 million people die from contaminated, untreated water. According to estimates, there are currently about 1.1 billion people who have virtually no access to clean water, as well as mum to every human being.

• **Panorama Brazil:**

Brazil's water situation is somewhat more comfortable than in other countries in terms of availability. Our country has 12% of the world's freshwater. Even with this abundance, the population suffers because distribution is irregular.

According to data collected by the Trata Brasil Institute, the Amazon has the lowest population concentration and has 80% of the existing surface water, while the Southeast, with the highest concentration, has only 6% of this resource.

Every second, on average, 2 million and 83 thousand liters of water are used in Brazil (or 2,083 cubic meters per second). In 1931, only 131 thousand liters per second were used, representing only 6.3% of current Brazilian use. However, the use of drinking water is expected to grow approximately 24% by 2030, surpassing the 2.5 million liters per second mark, as shown in Figure 2.

Figure 2: Overview of Brazilian drinking water withdrawal.
Source: LG ENVIRONMENTAL "http://lgambiental.com.br/noticias/estudo-da-ana-aponta-perspectiva-de-aumento- -do-uso-de-agua-no-brasil-ate-2030/" http://lgambiental.com.br/noticias/estudo-da-ana-aponta-perspectiva- -of-increased-water-use-in-brazil-by-2030/. Accessed on: 10/22/2019, 09:43.

Given the worrying situation we find ourselves in, we had the idea of combining our electrical engineering knowledge with a project that positively impacts the environment and its sustainability.

2. Introduction

2.1. Sustainability

The word sustainability comes from the term "sustainable", which in turn derives from the Latin *sustentare,* meaning to sustain, defend, favor, support, conserve and/or care for.

The concept of sustainability originated in Stockholm, Sweden, at the United Nations Conference on the Human Environment. This Stockholm conference, which was the first environmental conference held by the UN, drew international attention primarily to issues related to environmental degradation and pollution.

Later, in 1992, at the Conference on Environment and Development (Eco-92 or Rio-92), which took place in Rio de Janeiro, the concept of sustainable development was consolidated; which came to be understood as long-term development, in a way that the natural resources used by humanity are not exhausted.

Eco-92 also gave rise to Agenda 21, a document that established the importance of com- commitment of all countries to solutions to socio-environmental problems.

Agenda 21 has as priority actions the programs of social inclusion and sustainable development. tempting.

Sustainability is made up of a tripod, logically followed by three basic concepts, where each one of these aspects must be strictly linked and in a well-defined way, as shown in Figure 3.

Figure 3: Sustainability Tripod
Source: SICOOBCREDILUZ
https://www.sicoobcrediluz.com.br/sustentabilidade. Accessed on: 10/21/2019, 8:33 PM.

• **Environmental:**

A balanced environment is more than a concept; it is a law; maintaining it is everyone's obligation, including and/or certainly a business obligation. These actions are necessary and mandatory for any company, including the treatment of effluents and waste generated, control of pollutant gas emissions, and more. others.

Programs aimed at preserving flora and fauna, environmental education, construction of environmentally friendly buildings, and river pollution control are examples of actions that go beyond the requirements and contribute significantly to the environment.

• **Social:**

Actions that promote the educational education of both the professional and his/her family and the community within the company's reach, environmental education and social responsibility programs, encouragement of sports, actions that promote health and well-being, as well as professional training (which also influences aspects of workplace safety, since an educated professional is less susceptible to errors)

• **Economic:**

The Economic also comes in as a key factor, since it is what moves society, in a company it is no different, it is what will block or release investments in the two aspects already discussed previously.
Now, if this organization seeks sustainability, it will invest in new machinery, which initially requires investment but returns as savings, due to lower electricity consumption, for example.

2.2. Automation

The first movements towards automation emerged in the textile industry in the 18th century. This new concept began to be applied as steam engines became part of the production process, increasing the production capacity of factories, but it was still a very timid step given that the technology at the time was still quite archaic.

Moving forward in time, a new era begins in the industry. In this new stage, the automobile industry begins to dictate the pace of technological advances, and cars are produced using the production line concept.

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production, but what draws attention at this moment is the application of electricity in the process. The use of Basic electrical items already make the process much more robust and productive, electric motors are the driving machines of the new industrial scenario aligned with the new concept of in-line production.

What would our industry be without computing? Developments in computing have brought new tools to factories. Production processes now rely on logic-controlled equipment such as PLCs, frequency inverters, servo motors, and supervisory systems. This represents a paradigm shift in factory layouts, as cell-based production becomes the darling of large factories. The automotive industry once again uses Toyotism to dictate the direction of industrial production and, consequently, automation. However, it's reckless to associate automation solely with industry. From this third phase onward, the world experiences the massive emergence of other business models, such as commercial automation, with the emergence of ERPs and sales and logistics management systems; home automation, with the application of comfort and security systems; banking automation, with the emergence of new data storage and information processing systems; and so on.

The fourth industrial revolution, which is currently underway, is perhaps the one that has brought the most changes to people's lives and to commercial and industrial processes. Industry 4.0, as it is also called, brings with it the concept of digitalization. This new industry connects the entire production chain, from sales to after-sales service, through production, research and development, and even extending to relationships between companies and customers through social networks and apps. Now, it's possible to see the connected chain; we don't produce to sell, we sell to produce. All demand is precisely measured, and then production begins. Factories are becoming fully digitized, and artificial intelligence has taken over processes. Decisions are made at the machinery level through the application of sensors with built-in intelligence and management software with pattern recognition capabilities. Critical demands are also emerging at this time, such as the need for information security. Since systems are fully connected, the damage caused by system failures or hacker attacks is on a scale never before seen. Therefore, cybersecurity is essential to ensure systems are not vulnerable. It is possible to visually follow how the developments outlined in the text above occurred in Figure 4.

Figure 4: Automation Timeline
Source: Online Quality
https://qualidadeonline.wordpress.com/2015/03/18/as-tendencias-da-automatizacao-industrial/. Accessed on: 11/02/2019, 12:50 PM.

2.3 What is the Cloud?

The first known mentions of the Internet date back to 1962, when JCR Licklider of MIT wrote some memos discussing this new concept. Since then, we have seen the exponential growth of the WWW (World Wide Web), which is nothing more than the global internet network, that is, where we exchange information, store data, do business, and have fun. Interestingly, whenever a technology develops, it ends up "pulling" many other technological advances. It is worth mentioning that thanks to the development of the Internet, industry has been able to move from archaic production methods to automated production. For this, many "tools" needed to be developed, such as industrial communication networks: Ethernet, Profibus, DeviceNet, TCP/IP.

IP, among others; industrial automation equipment such as PLCs, frequency inverters, softstarters, and various types of sensors; ERP software, which are essentially applications that manage a production process globally, from purchasing inputs to issuing invoices after the sale; CRM (Customer Relationship Management) software, which manages the entire customer value chain, from identifying a business opportunity to closing the sale. Countless technological developments have emerged from the development of the Internet, as all these "tools" are connected to it in some way.

However, at some point, the need for competitiveness reached such a high level that simply being connected to the internet was no longer enough to make companies globally competitive. It's worth remembering that for a company to become competitive, a key element is its IT (information technology) development, both industrial IT and corporate IT, such as operations management (ERP) and customer/market relationship management (CRM). For all of this to be possible, the company's IT infrastructure must be large-scale, robust, and reliable.

Given this new scenario, cloud computing has become an indispensable tool for making businesses highly competitive. Companies can now develop their operations to a level of excellence, as they don't have to invest heavily in IT infrastructure, allowing them to focus on what really matters: their business. With the cloud, companies purchase network access as a service, and the access provider manages this infrastructure. This allows businesses to grow rapidly and become more efficient, as there are significant reductions in implementation, maintenance, and staffing costs.

In 2013, global investment in cloud-based services reached $47 billion. And this number was projected to double and surpass $100 billion in 2018 as companies increased their investments in cloud services as the foundation of their new, more competitive products. Author: SalesForce

How the cloud is structured and the advantages of using this type of technology

The concept of cloud computing is much simpler than it seems. In reality, what exists is an extremely large network of servers spread across the world, connected to each other, forming a vast infrastructure that allows individuals and companies to store their information without having to store it on nearby servers. In other words, a company in São Paulo could be storing its data on servers in the United States, or Germany, or even both simultaneously. This data is accessible via the internet, which is why, as mentioned above, there is no need to invest heavily in network infrastructure, as anyone can purchase the internet access service.

cloud, saving your data without worrying about system maintenance. The great thing about this concept is that it has no limit; that is, with each connected server, the network size increases proportionally to the size of that server, as illustrated in Figure 5.

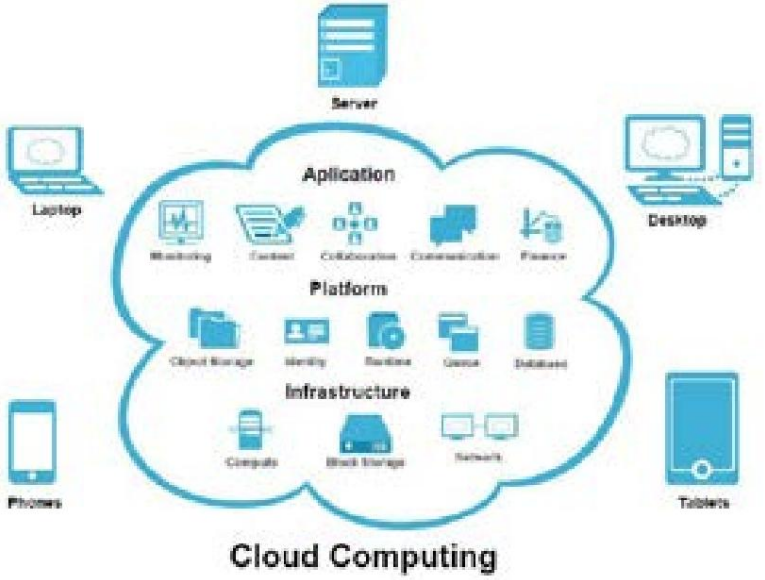

Figure 5: Cloud Computing
Source: WIKIPEDIA.
https://en.wikipedia.org/wiki/Cloud_computing#/media/File:Cloud_computing.svg. Accessed on: 12/09/2019, 22:29 Hours.

Applying cloud computing to business has brought enormous advantages as seen below:

2.3.1 Cost Proportional to Usage

Before cloud computing, companies had to oversize their network infrastructures to avoid being left high and dry when they needed them most. In the cloud, you only pay for what you use, and there are no additional costs for specialized personnel or system maintenance and improvements—all of this is covered by the provider.

2.3.2 Always the Best Service at No Additional Cost

In the traditional model, all infrastructure and software require significant maintenance costs when network capacity needs to be increased or software updates are required. In the cloud, all these improvements are provided by the company providing the service at no additional cost.

2.3.3 Adaptability to Business Reality

As mentioned earlier, imagine a retail company, which is a highly seasonal market, especially during holiday periods like Christmas, Children's Day, etc. If it wants to maintain its own infrastructure, it must scale its structure based on peak periods, but this is a huge expense for short periods, meaning it invests money that will remain "idle" most of the time. Using a cloud-based service, it is possible to adapt the capacity of your business to emerging demand automatically and with extreme adaptability. That is, if the number of requests for a product increases, the company will be comfortable serving its customers, and when demand increases, it will

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decreasing will keep your business going without unnecessary investment.

2.3.4 Accessibility

Nowadays, most people aren't tied to specific locations, especially with the rise of *co-working* spaces and the rise of multilateral businesses. People travel extensively and need real-time, anywhere access to their information. Because cloud network infrastructure is globally distributed, anyone can access information anytime, anywhere via the internet.

2.3.5 Centralization

We've often seen companies invest vast sums of money in software to manage their operations, and the biggest problem of all is that the software isn't compatible. With cloud-based services, all software can run on web platforms, enabling easy and robust integration, thus streamlining business management.

2.3.6 Easy Monitoring.

As part of the service offered, it is possible to view reports that show how the network is being used, facilitating decision-making for business managers.

2.3.7 Faster Recovery After Accidents.

Imagine a company that has its own network infrastructure, servers, etc. If that company experiences a catastrophe like a fire, for example, there is no way to recover the information that is stored there.
Once the entire history, know-how, customer base, company strategy, etc., are lost, the company will almost inevitably close its doors, as it will practically have to rebuild everything from scratch. Now compare this company with one that uses cloud-based services and suffers the same disaster; the company's ability to recover greatly increases because the company's core information is secure.

2.4 Internet of Things (IoT).

The cloud has been discussed, enabling companies and individuals to run their businesses without the need for IT infrastructure. In industry, IoT is a hotly debated topic.
Having the necessary infrastructure for the industry to operate in an intelligent and autonomous manner, called Industry 4.0, and not having equipment and systems that can transfer data to this network is useless.
a lot of things.

IoT, or Internet of Things, is another concept that deals with operational intelligence in business. This intelligence is developed through the application of a series of layers of intelligent devices and systems that enable the arrangement of devices and systems to receive information, analyze it, and make decisions with minimal human interference.

There are several layers of IoT, each responsible for operational intelligence at different levels conform illustrates Figure 6.

Figure 6: IoT architecture.
Source: TCC Group.

2.4.1 Peripherals

Peripherals can consist of auxiliary devices that can be used to send or receive data and information, being divided between input and/or output devices.

2.4.2 Process Device.

The processing device is a hardware that will process all the data that the peripherals send to it and can then resend it to another process, in the case of IoT, a cloud or digital connection network, and can work with processing protocols in order to generate greater security in sending and receiving.

2.4.3 Connectivity

Connectivity to the IoT connection network can be done in several ways, whether with or without cabling, for example: Wireless, Bluetooth and 4G/5G.

2.4.4 End User

The user must have some way of viewing and/or controlling data related to the system to which it is linked, which may be a platform developed especially for such system or existing platforms.
tests that have greater structure and/or ease of use, such as Dashboards.

3. MATERIAL AND METHOD

3.1 STAR and the Benefits of Reusing Water

The benefits of STAR are immense and are mentioned below:

- Reduce waste of natural water;

• Reduce water waste from utilities;
• Generate opportunities for better use of natural water;
• Correct problems related to global water distribution and storage, avoiding water crises;
• Correct problems and reduce expenses with concessionaires (water and sewage);
• Reduction in dealerships' maintenance expenses;
• Make the tall project sustainable;

4. STAR Project (Reuse Water Treatment System).

About the project:

STAR is a water treatment system used as a proposal to exemplify the cloud connectivity of automated systems. This final project will demonstrate all the electrical and electronic designs, the fully commented system programming for STAR's automation, and the connection to the IoT platform. All of these projects will allow anyone to reapply this application to any other automated system, as the approach will be very similar.

4.2 Installed Project

In Figure 7 you can get an idea of what a reuse water system installation like the one below would look like. STAR:

Figure 7: Example of Water Treatment System.
Source: TCC Group.

Process flowchart, as illustrated in Figure 8.

Process Flowchart.

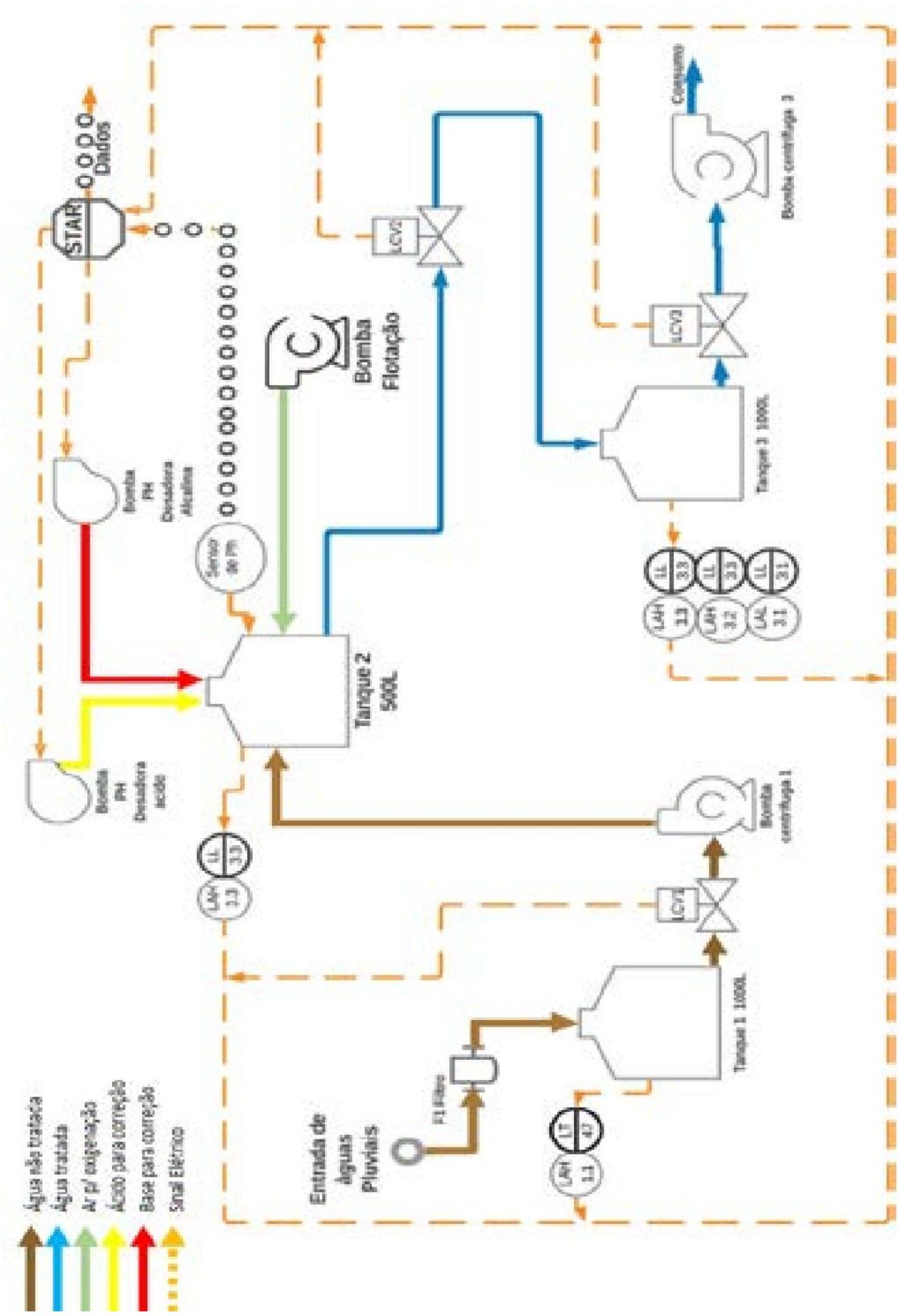

Figure 8: Process Flowchart.
Source: TCC Group.

4.3 Materials Used

Materials used, as illustrated in Table 1.

Amount	Item
2	1000l water collection tank
1	500l water collection tank
3	Solenoid valve
2	Water pump
5	Level sensors
1	Engine
2	Metering pumps

Table 1: Materials Used.
Source: TCC Group.

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1. **Important Definitions**

The water produced by the system **is NOT** suitable for human consumption, such as washing dishes, clothes, bathing, or cooking. This water is reclaimed water and is only suitable for washing floors, walls, cars, watering plants, flushing toilets, and other non-consumption purposes.

The treatment system processes batches of 500L at a time.

The system starts the process if tank 1 has 500L available and tank 3 is at half capacity, that is, with only 500L of water.

2. **Receiving Collected Water**

Water will be received by tank 1, which in the project in question is estimated to hold 1,000 liters. This tank will have an intermediate level sensor that "alerts" the system that there are 500 liters of water available for treatment.

It was established that batches of 500 liters of water will always be treated, respecting the conditions of the item above.

A high level sensor was not considered for tank 1, as there will be a "thief" that will let the water fall in case of overflow, this condition is possible if tank 1 and tank 3 are full.

When the treatment process begins, water is pumped from tank1 to tank2, which measures and controls the pH. For this, the system sends a signal to open valve1 and a signal to turn on pump1.

3. **pH Measurement and Treatment**

Water will be pumped until the high level sensor (ch2.1) in the tank detects water, at which point pump1 and valve1 will be turned off. Then, pH measurement and control will begin.

In this second stage, a pH sensor measures the water's pH. If the pH is not suitable for use, a dose of acid or base will be added depending on the water's condition. This is done by activating small metering pumps. After adding the pH correction solution, a float, activated from the beginning of the process, will continuously mix the water through a propeller that simultaneously oxygenates the water. This measurement and correction process will continue until the water reaches the ideal pH.

After reaching the ideal pH value, the water will be drained into tank 3 only by opening valve 2, as tank 2 is at a higher level than tank 3.

4. **Water Storage**

The water will be stored in tank 3. If tank 3 only has 500 liters, another water treatment cycle will begin, as the aim is to store as much water as possible so there is no shortage during periods of little rain.

5. **Use**

The use of water will be released through a pump to pressurize the water for consumption by pressing a button that will activate the pump.

The system will not allow pump3 to be activated if the water level is too low, that is, when the ch3.1 level is not detecting water.

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6. Hardware

6.1. CPU

The board used in this project was the ESP32-WROOM-DEVKITC (as shown in Figure 9), which is a board dedicated to IoT projects and has several items for automation such as bluetooth/wifi antennas.)

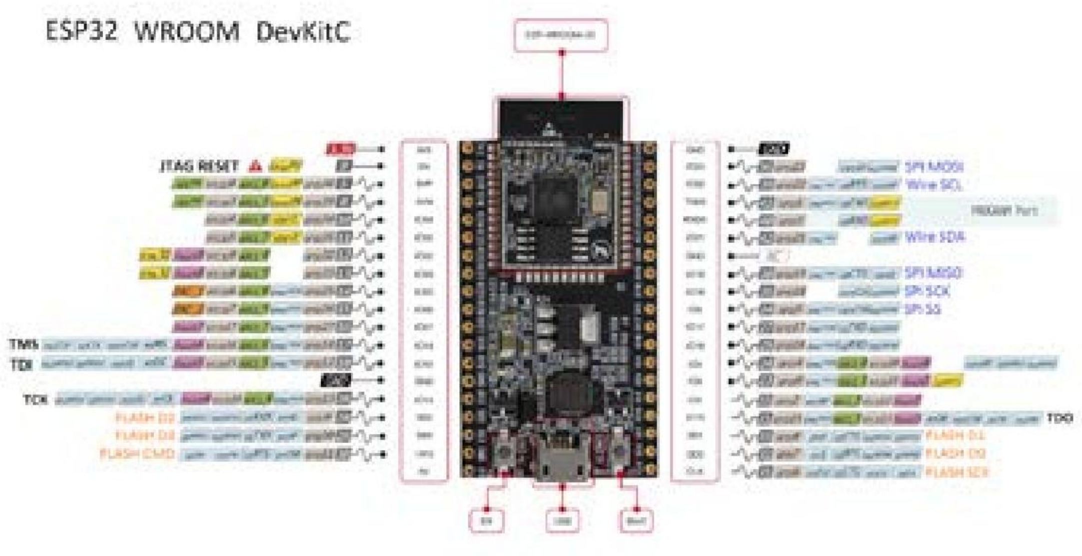

Figure 9: CPU.
Source: BOTNROLL. https://www.botnroll.com/pt/varias/2452-placa-de-desenvolvimento-esp32-es-pressif.html . Accessed on: 09/13/2019, 5:39 PM.

6.2. Connecting the Boards

This diagram shows all the connections for each board, with details of the wire connections between the boards. See Appendix I.

6.3. LED board.

This board only serves to display in real time which items are being activated. See Appendix II.

6.4. Relay Output Board.

The relay output boards are the drivers for operating the valves and pumps in our system, which transmit power to drive the entire system. See Appendix III.

6.5. Level Sensor Board.

The level sensor board will acquire the position information provided by the sensors and send this data to the ESP32, which can then make actuation decisions based on the water levels at each stage of the process. See Appendix IV.

6.6. Technical Details.

See Annex V for details of the electronic system for protecting and activating the devices.

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6.7. I/O Table

I/O table, as illustrated in Tables 2 to 5.

POWER SUPPLY BOARD:		
24 V	Drives	
12 V	Sources	
3.3 V	Control board – ESP32	
GND	General	
DRIVER OUTPUTS - RELAY OUTPUT:		
FOOD:		
24 V		
3.3 V		
GND		
SIGNS:		
VS1	TANK VALVE 1	IO0
VS2	TANK VALVE 2	1017
VS3	TANK VALVE 3	IO12
B1	PUMP 1	IO4
B2	BOMB 2	105
B3	BOMB 3	1015
B4	PUMP 4	1019
B5	PUMP 5	IO21

Table 2: I/O Table.
Source: TCC Group.

DIGITAL INPUT BOARD LEVEL SENSORS:		
FOOD:		
3.3 V		
24 V		
GND		
SIGNS:		
LEVEL KEY 1	CH_1	1016
LEVEL 2 KEY	CH_2	IO02
HIGH LEVEL 3 SWITCH	CH_3_1 IO18	
LEVEL SWITCH 3 MEDIUM CH_3_2 IO13		
LOW LEVEL 3 SWITCH CH_3_3 IO27		

Table 3: Digital Input Board - Level Sensors.
Source: TCC Group.

TRANSISTOR OUTPUT DRIVER BOARD - LED:	
FOOD:	
24V	
GND	
SIGNS:	
LED VALVE 1	IO0
LED VALVE 1	1017
LED VALVE 1	IO12

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LED PUMP 1	IO4
LED PUMP 2	105
LED PUMP 3	1015
LED PUMP 4	1019
LED PUMP 5	IO21

Table 4: Transistor Output Driver Board - Led.

Source: TCC Group.

CONTROL BOARD - DIRECT SIGNALS:		
FOOD:		
3.3V		
SIGNS:		
PH	pH 1032	
BT LEAGUE	BT1 IO25	
BT turns off	BT3 IO34	
BT OUTPUT	BT2 IO22	

Table 5: Direct Signal Control Board.

Source: TCC Group.

7. Software

To program the system, the Arduino IDE was used due to its ease of finding support content and the large number of references for ESP32 projects available on the internet.

8. Cloud Communication

To make the system communicate with the cloud, the hardware control (ESP32) was associated with the Ubidots platform, which is an environment developed to facilitate the creation of IoT applications, offering several creation possibilities with greater ease of use.

5. RESULTS AND DISCUSSION

9. Project Communication Architecture

In the project architecture it is possible to observe how the project can be divided into 3 blocks, being: Local System, Cloud and User Location, as shown in Figure 32.

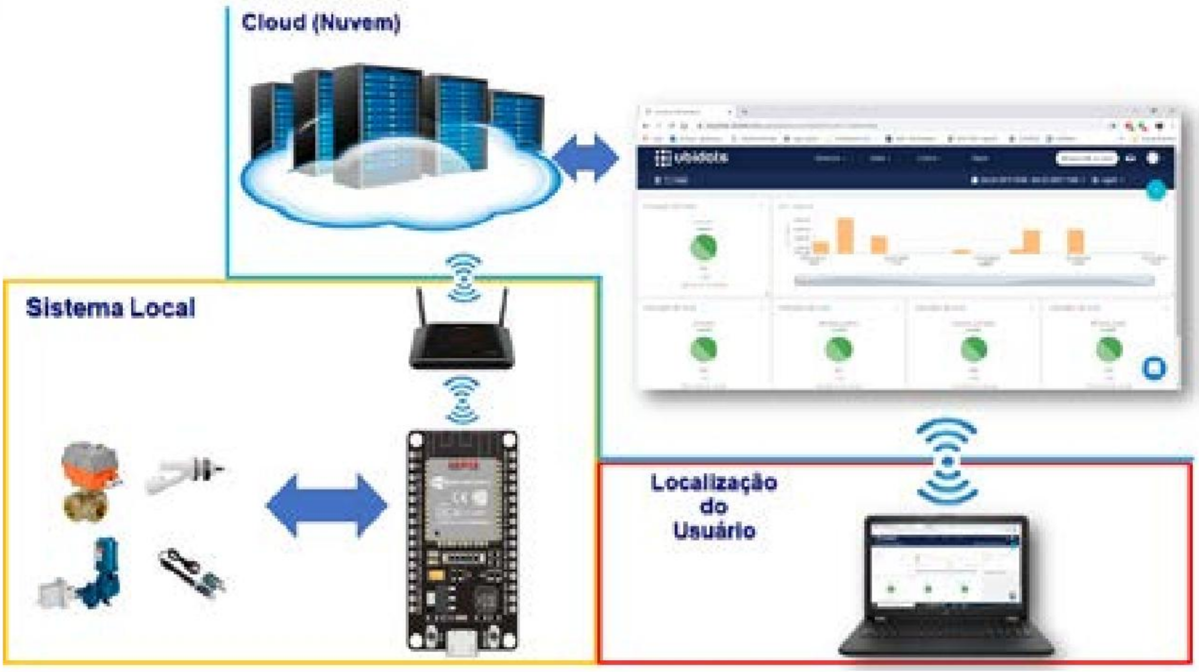

Figure 32: STAR Project Communication Architecture
Source: TCC Group.

10. Technical and Financial Study of the Project

10.1. Adopted Assumptions

In order to estimate the project's costs and return time and decide whether this solution is actually viable, it is recommended to adopt some premises. Below are some established parameters to make the calculations easier to understand:

1) (F) Family size = 4 people
2) (P) Number of apartments in the building = 20 apartments/families1
3) (C) Average water consumption for a family of 4 people = 8m³/year
4) (S) Percentage of water used in toilet flushing = 14%
5) (L) Percentage of water used for cleaning common areas = 5%
6) (A) Water catchment area = 300m²
7) (Pr) Average rainfall per year = approx. 1.34m
8) (CP) Project Cost = approx. R$8,000

It is important to emphasize that reused water cannot be used for consumption purposes, that is, it cannot be drunk, washed dishes/clothes, bathed, etc. Therefore, the only purposes for which reused water can be used are for cleaning common areas such as balconies and verandas and for feeding the
flushing in toilets.

10.2. Calculation Report

Note: To understand the calculation made in Table 6, a form was placed above and the actual account below, the letters contained in the form are explained in item 13.1.

1 The application of this solution in residential condominiums is being studied at this first stage.

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1- Total water consumption in the residential building in the year (m³/year)	GT = (P*C)*12 Form GT = (20*8)*12 = 1920[m³/year]
2- Water consumption for toilet flushing per year (m³/year)	GS = GT*S Form GS = 1920*14% = 270[m³/year]
3- Water consumption for cleaning common areas per year (m³/year)	GL = GT*L Form GL = 1920*5% = 96[m³/year]
4- Total reusable water	GR = GS+GL Form GR = 270+96 = 366[m³/year]
5- Water available per year	AC = A*Pr Form AC = 300*1.34 = 402[m³/year]
6- Monthly water consumption in the building in question so	GM = GT/12 Form GM = 1920/12 = 160[m³/year]

Table 6: Water Consumption Calculation Report in [m³/year]
Source: TCC Group

Water consumption profile in a building with 20 families, as shown in Figure 33.

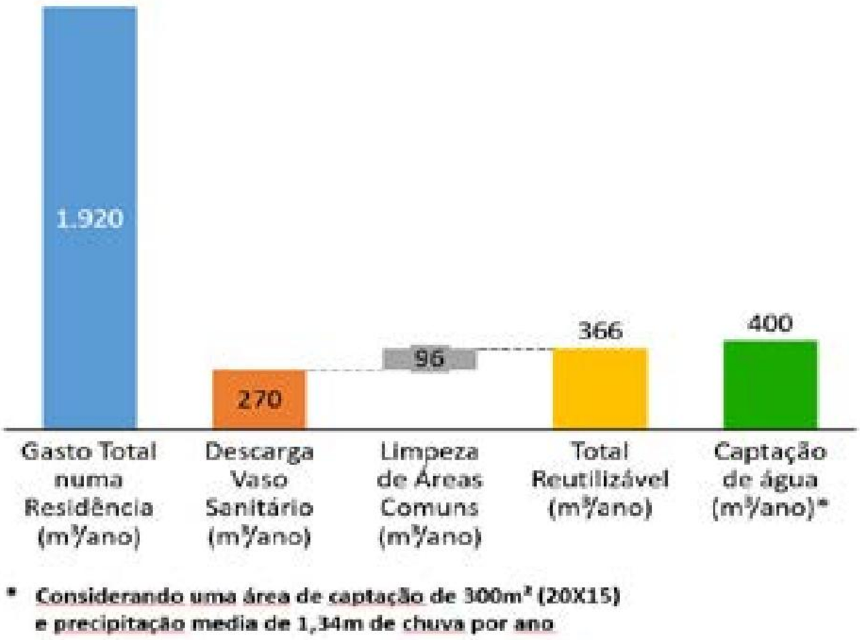

Figure 33: Water Consumption Profile in a Building with 20 Families.
Source: TCC Group.

In order to convert the values in [m³/year] into [R$/year] and have a financial overview of water consumption, it is necessary to know which Sabesp rate will be applied. To do this, you must know the monthly consumption and then check the tables provided on the internet to see which rate will be used. It is also worth remembering that in São Paulo you pay twice the water rate, as one is for the use itself and the other is for the use of sewage, that is, you pay to drain the used water into the sewage network.

Since monthly consumption is approximately 160 [m³/month], the applied rate will be on average R$9.00 and the total amount paid per m³ of water will be R$18.00 (Water + Sewage). See Table 7 for the accounts for converting consumption and calculating return on investment, and Figure 34 graphically displays the results of the conversion, also considering the project cost and the savings with the application of STAR.

7- Total water consumption in the residential building in the year (R$/year)	GTr = GT*18 Form GTr = 1920*18 = 34,560[R$/year]
8- Average savings (R$/year)	GRr = GR*18 Form GRr = 366*18 = 6,588[R$/year]
9- Amount spent applying reused water	GF = GTr-GRr Form GLr = 34,560-6,588 = 27,972[R$/year]

10-	Return on investment time [months] TR = GRr/CP	Form GRr = 8000/6,588 = approx. 14[months]

Table 7: Water Consumption in [m³/year]
Source: TCC Group

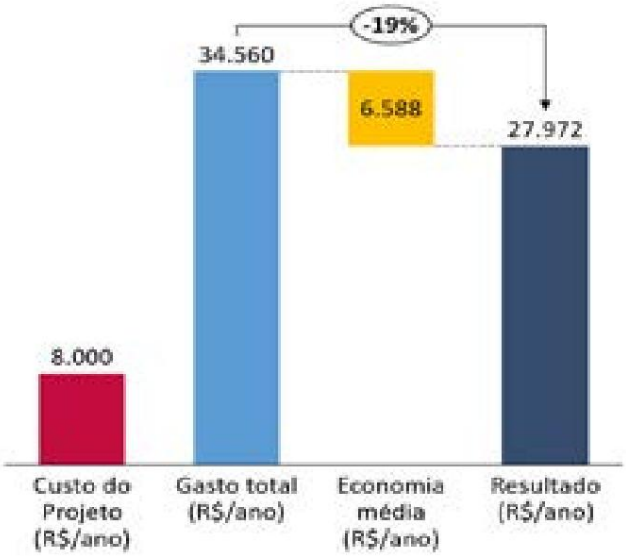

Figure 34: Conversion of Expenditure in [m³/year] to [R$/year]
Source: TCC Group.

11. Evaluation of Results Obtained.

Initially, it was difficult to find documentation for the ESP32's I/O ports, as the board can be developed and sold by several companies. Each company can assemble it according to their own wishes, so finding the exact listing for this project's board was somewhat difficult.

As for the IDE, for development it was necessary to interpret the characteristics of the Arduino IDE for programming, which has specific characteristics even when using the C language.

It was also necessary to develop great knowledge regarding the connection to the cloud (Cloud) as it is a recent technology and can be developed in different ways, in this case UBIDOTS was chosen, which has a practical and simple supervisory system and can be used in different ways.

Although there are currently more powerful module models on the market, with greater availability of inputs and outputs that logically allow for a greater number of points for obtaining information and controls, the architecture presented momentarily allowed us to obtain sufficient resources for data analysis.

Research into pH treatment was necessary, as water can be corrected in a variety of ways. Thus, a method for interpreting and correcting the data had to be developed, which required several tests.

As an initial test, we simulated the activation of two LEDs already connected via IoT and observed whether they responded to commands generated via the network, with one indicating the activation of a sensor and the other of a switch. It was at this point that we observed the relationship between the activation time via the computer keyboard and the activation on the experimental board, as shown in Figure 35.

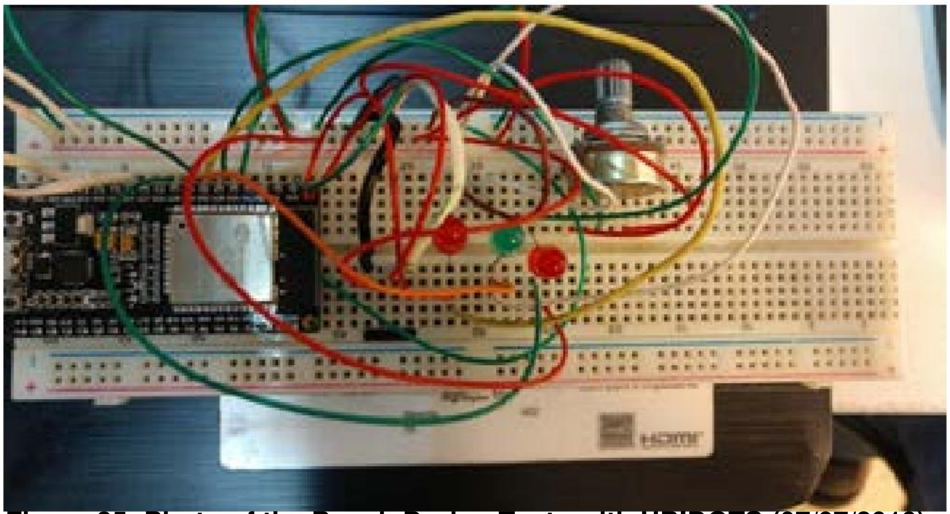

Figure 35: Photo of the Bench During Tests with UBIDOTS (07/07/2019).

Source: TCC Group.

During initial testing, a small time difference was immediately noticed between the activation of a component, be it a relay or sensor, and the data collected and displayed on the computer's on-screen (cloud) controls. This event was initially corrected (minimized) by adjusting and better reconciling the times requested in the software's delay routines, along with some calibrations of the electronic components. It was later determined that these errors were also caused by variations in transmission speeds from the internet service providers (ISPs) operating at the time, the local network servers. After resolving these temporary issues, some data records were obtained, shown in Figure 36, demonstrating the efficiency and accuracy of the data received when activating the test LEDs, indicated in Figure 30 as sensors and switches.

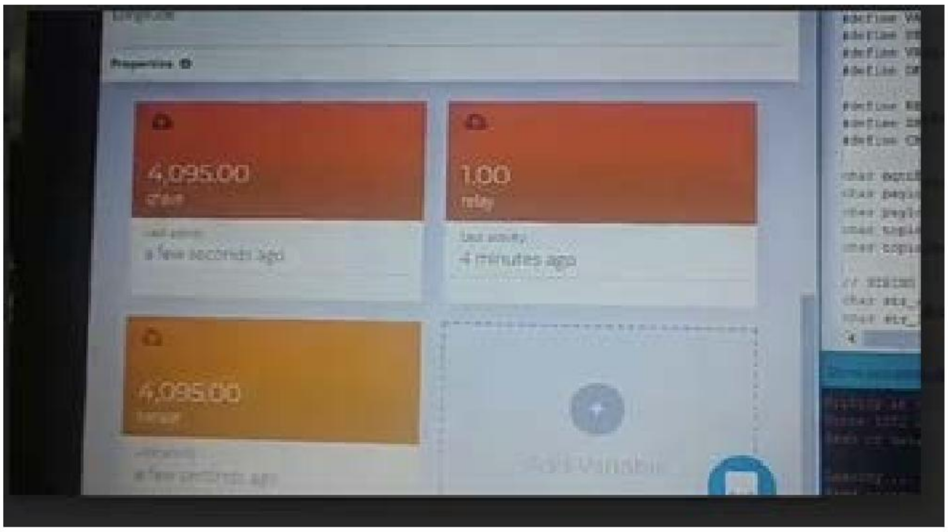

Figure 36: Photo of the Bench During Tests with UBIDOTS (07/20/2019).
Source: TCC Group.

It was expected that there would be considerable difficulty in connecting the equipment involved—the computer and the ESP32 Arduino IDE board—but this did not occur because it already comes with very interesting solutions, such as an Ethernet communication module, which makes things much easier. Much of the project time was spent on software development. The screens in the Ubidots environment are very user-friendly, which made it easier for many to obtain the data shown, as shown in Figure 37. This allows us to understand the wide range of possibilities for collecting data from process contro

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implemented, such as signaling of drives, status of interesting quantities in the process, occurrences references to failures due to various causes.

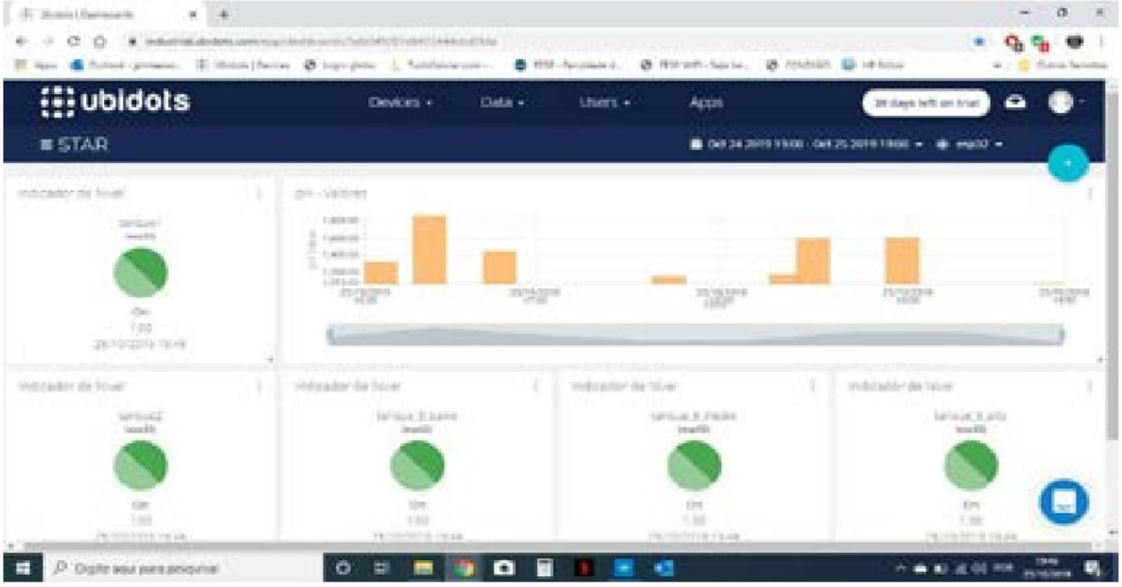

Figure 37: Photo taken from the Data Acquisition Screen (10/25/2019).
Source: TCC Group.

Once this first phase of initial testing was completed, it was then possible to continue testing the control architecture proposed in the STAR System according to the sequence illustrated in Figures 38 to 43.

• Tests related to project automation:

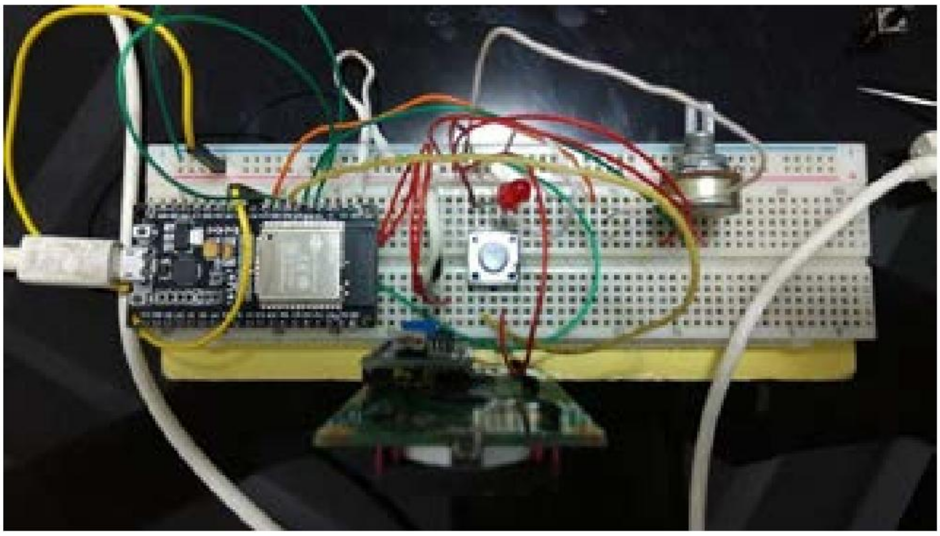

Figure 38: Photo taken during tests simulating automation (09/07/2019).
Source: TCC Group.

Then, some tests were started regarding the software's routines and subroutines regarding the project's automation, checking the project's routine step by step, where difficulties were encountered regarding the language.

gem and project flow, thus solving each part of the software.

Tests were carried out to verify this communication between hardware and cloud, using two fixed values that were published in the cloud and controlling an LED with a virtual on/off button that was activated on the board.

Tests were carried out to evaluate and obtain some readings from the display and make some necessary adjustments to improve clarity.

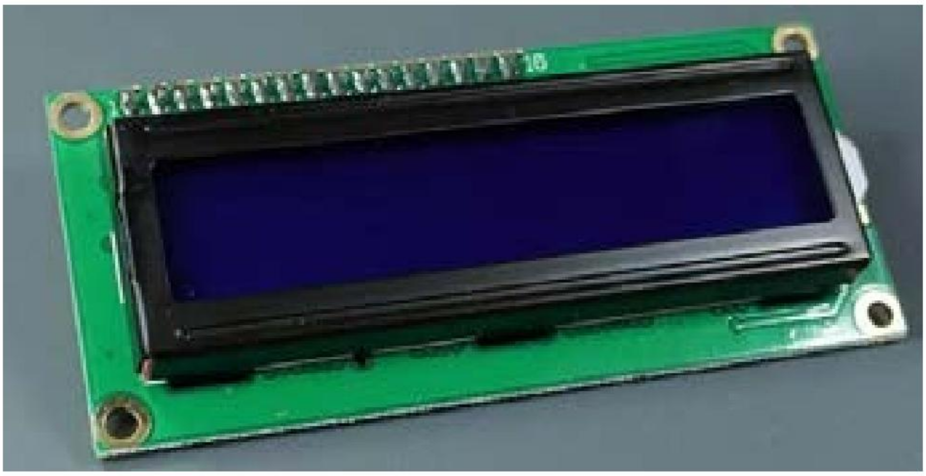

Figure 39: 16x2 Display.
Source: RANDOM NERD TUTORIALS.

https://randomnerdtutorials.com/esp32-esp8266-i2c-lcd-arduino-ide/. Accessed on: September 14, 2019, 8:30 PM ras.

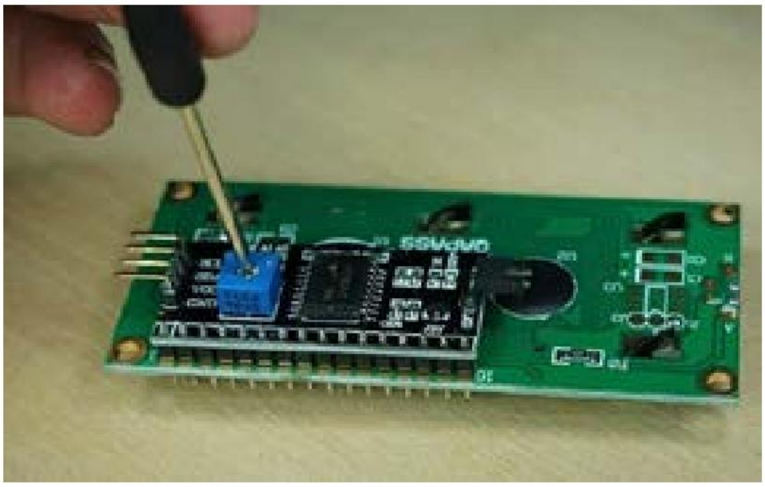

Figure 40: 16X2 Display Contrast Adjustment.
Source: RANDOM NERD TUTORIALS.

https://randomnerdtutorials.com/esp32-esp8266-i2c-lcd-arduino-ide/. Accessed on: 09/14/2019, 8:30 PM.

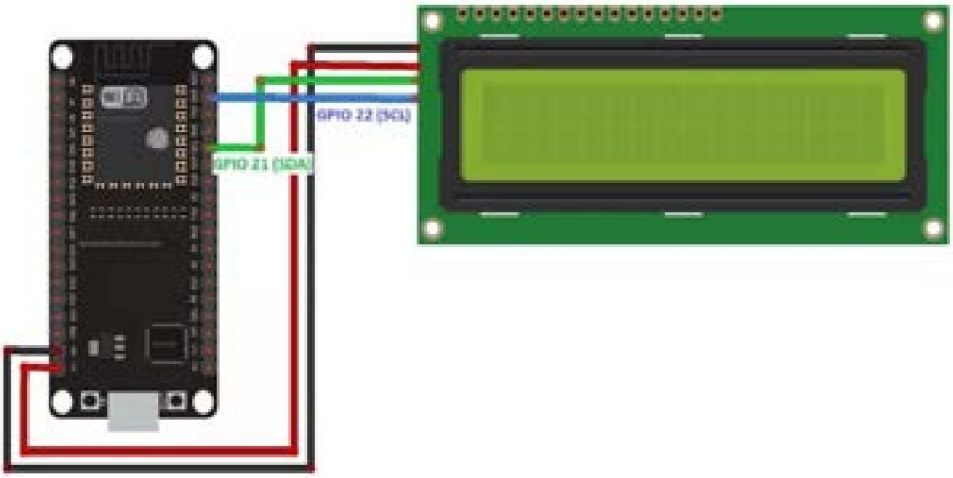

Figure 41: Display Connection Diagram.
Source: RANDOM NERD TUTORIALS.

https://randomnerdtutorials.com/esp32-esp8266-i2c-lcd-arduino-ide/. Accessed on: 09/14/2019, 8:30 PM.

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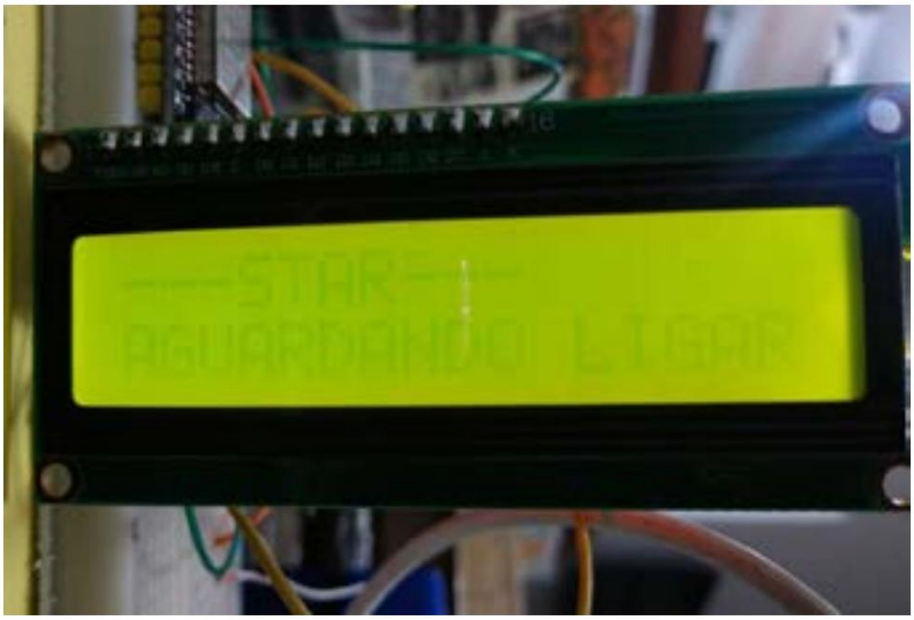

Figure 42: Photo taken during display testing (08/24/2019).
Source: TCC Group.

Figures 43 and 44 show the first screens of the system, indicating that it is ready to start:

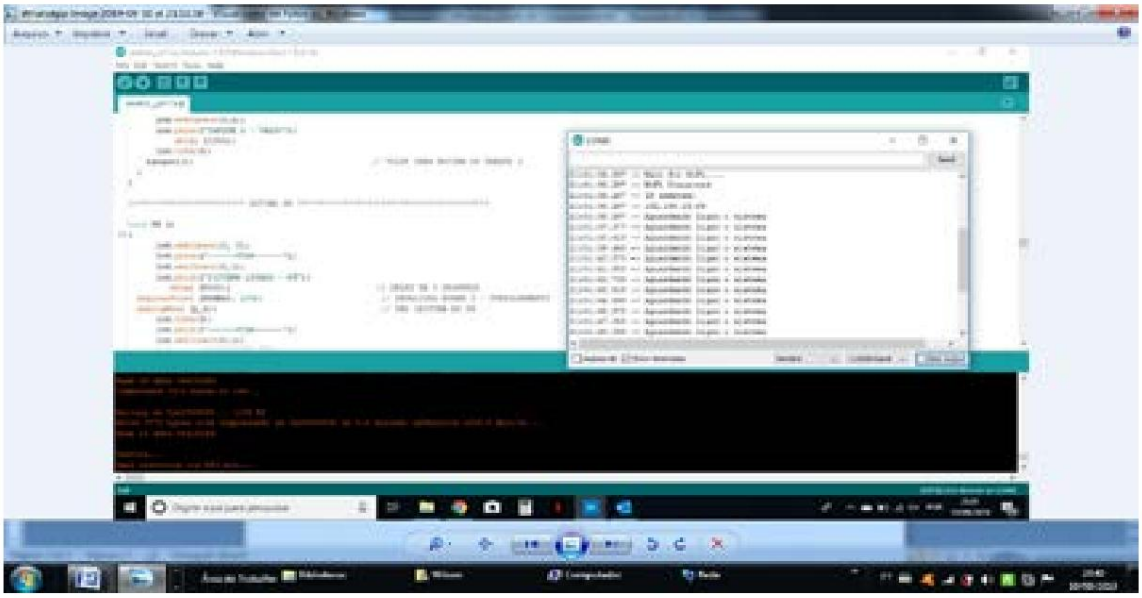

Figure 43: Photo During Automation Tests and Results (08/30/2019).
Source: TCC Group.

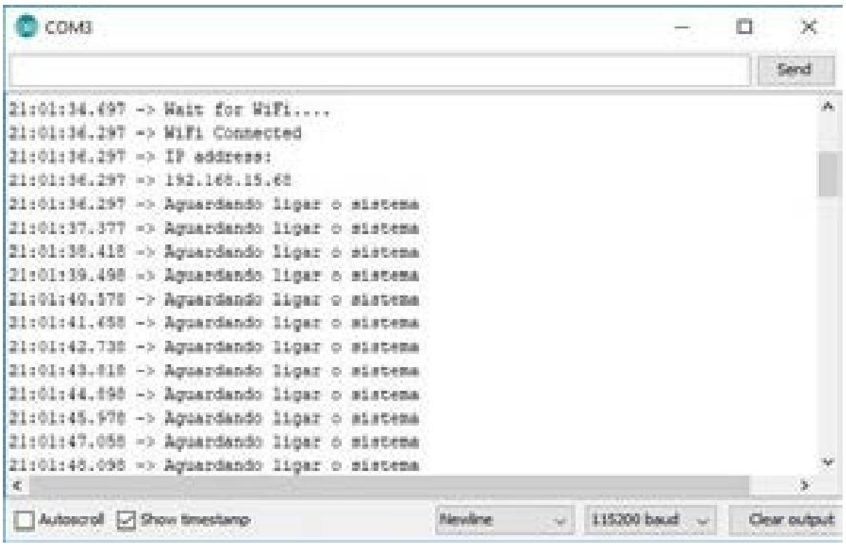

Figure 44: Software Return Photo (08/30/2019).
Source: TCC Group.

The tank monitoring routines were tested, such as the status of the momentary condition of each tank, that is, whether it indicated a full or empty level, as illustrated in Figures 45 and 46, as we simulated on the hardware board, it responded satisfactorily with the indication on the screen of our computer in the cloud environment.

• Test on/off actuation of pump BT1 and lock switch Ch1 as open or closed. Tank 1 initial storage empty, as indicated in Figure 46, status change to full:

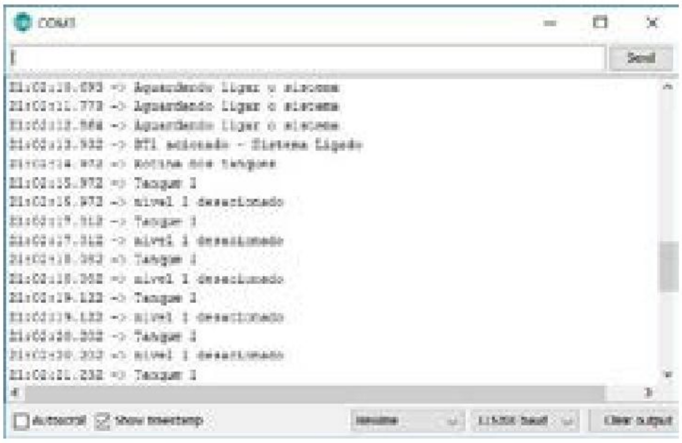

Figure 45: Software Return Photo (08/30/2019).
Source: TCC Group.

• Tank 2, initial simulation as empty, as indicated in Figure 46 and simulation of status change to full:

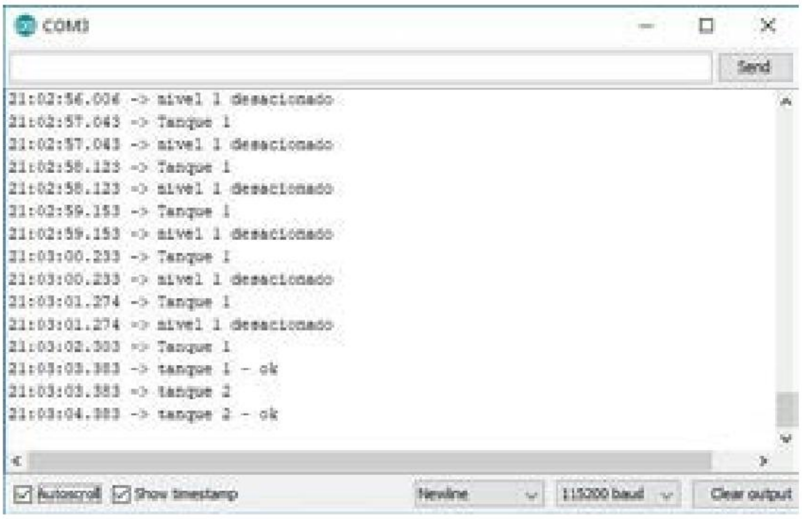

Figure 46: Software Return Photo (08/30/2019).
Source: TCC Group.

Hardware pH measurement as base, indication as base (Figure 48), hardware change from base to acid, verification of indication shown on screen. During the flotation process, pH correction required a delay routine, which is mandatory because it involves analyzing the results of physical-chemical experiments, requiring a sequence of collection, analysis, and, if necessary, correction. This sequence requires great attention because it is directly influenced by the volume of the substance being treated. After the pH correction sequence, and the pH presented the desired index, which is closest to the range between 6 and 7, the status of the Ch2 lock switch indicated in Figure 47 was checked, enabling gravity flow for the sequence that would be the storage of ready-to-use reused water.

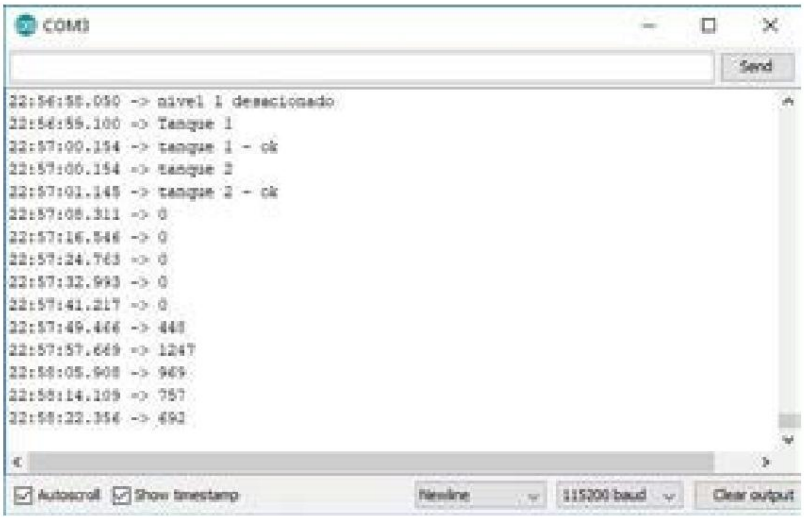

Figure 47: Software Return Photo (08/30/2019).
Source: TCC Group.

• Tank 3, as this tank is basically for storage and release to the user, the status of the low, medium and high level switches and the status of pump B2 on/off were tested.

12. Opportunities for Improvement

12.1. Introduce concepts of Artificial Intelligence, Machine Learning and Business Analytics.

By applying these concepts, STAR becomes a much more complete and intelligent solution than a simple automated system connected to the cloud. The system will be able to perform data analysis and all-

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sea decisions based on information patterns, it will also be possible to make comparisons between residences and make the system's operation even more sustainable.

12.2. Remote Operation

The STAR supervisory system is programmed only to display information provided by the system, but this means the operator has little autonomy when viewing the system remotely. In other words, the operator will always have to go to the panel to make any interventions. Implementing the proposed improvement of turning the supervisory system into an operator interface will make operation much more streamlined and greatly increase the comfort of those responsible for the system, making the STAR operable even from great distances via smartphones. An example of this is seen in Figure 48.

Figure 48: Remote Systems Operation
Source: https://engprocess.com.br/operacao-remota/. Accessed on: 10/14/2019, 1:20 PM.

12.3. Connection to power management system

In addition to operating the system remotely, another advancement that can be implemented in the project is connecting STAR to energy management systems, making resource management much more comprehensive. In other words, it will be possible to see the use of electricity and water, making decision-making about global resource consumption more assertive and strategic.

FINAL CONSIDERATIONS

Based on the study conducted for this final project and discussions with our professors throughout the project, we understand the importance of the concept of sustainability and how the connection between sustainability and engineering can create significant opportunities. It is clear that this project offers significant improvements that can be implemented, and that promising business models for the future may emerge. Below are some important points to consider for future development.

later.

13. Application Opportunities

13.1. Applications in condominiums of the My House My Life Program

The application of water reuse systems in condominiums of the Minha Casa Minha Vida Program brings a new face to the program. From this milestone, it is possible to highlight not only the improvement in people's lives and social ascension, but also the focus on sustainability. In other words, the existence of the tripod of sustainability is seen in practice, whose pillars are **socially fair, economically viable** and **environmentally balanced solutions.** It is possible to imagine the amount of water saved in a condominium like the one in Figure 49 if a system like STAR is incorporated into the project.

Figure 49: Condominium of the My House My Life Program in Barra do Coroa-MA
Source: http://www.barradocorda.ma.gov.br/site/prefeitura-sorteara-1-000-casas-do-programa-minha--home-my-life/. Accessed on: 10/15/2019, 2:20 pm.

13.2. Commercialization of Reused Water

This market needs to be studied in more depth and the applicable legislation understood in greater detail, but it's clearly a very promising niche. Just imagine the countless uses for which reclaimed water can be used, such as washing large logistics fleets, buses, or cars; cleaning large industrial and/or logistics yards; cleaning streets and sidewalks; cleaning buildings, and so on. If reclaimed water were used for every application that doesn't require consumable water, the savings would be virtually incalculable, making our cities increasingly smart and sustainable. The city of São Paulo already distributes this type of water, as shown in Figure 50.

Figure 50: Reused Water Distribution Truck.
Source: https://www.boavontade.com/pt/ecologia/o-que-e-agua-de-reuso-da-pra-beber. Accessed on: 10/15/2019, 2:15 PM.

Next Steps.

• Develop an Academic article and submit it to a national conference.

• Make STAR code better structured using VScode.

• Patent the Product.

• Structure projects for new and existing projects, considering costs and

models of action for both cases.

• Structure a Business Plan to start a startup.

•Develop a market for the commercialization of reused water

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