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BRAZILIAN FUEL CELL AUTOBUS

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Resumo: *The energy transition to a sustainable world has gained more and more importance nowadays. Sustainability refers to the ability of fulfill economical, political, social and energetic needs wisely, without destroying the possibilities of the future generations fulfilling it as well. The air pollution and CO2 emission are an important issue worldwide and new technologies plays a big role to solve these questions.*
"A sustainable city is a city designed considering the environmental impact, inhabited by people dedicated to minimization of required inputs of energy, water and food, and waste output of heat, air pollution - CO2, methane, and water pollution." Thus, it refers to both a structure and the using of sustainable processes: from siting to design, construction, operation, maintenance, renovation, and demolition.
According to the National Energetic Balance - 2014, in 2013 the total of carbon dioxide (CO2) emissions in Brazil was 459 millions of tons, transports sector is responsible for most of it (47%). Moreover, in the state of Bahia 59% of the energy comes from non- renewable sources, of which 51,3% are oil and derivatives, also the final consumption of liquids fuels has increased in 5,3%.
Furthermore, transport is the second biggest issuing of CO2 in the state, it consumes 17,6% of the energy given internal offer, what represents 50,9% usage of oil, derivatives and natural gas.
A promising technology is fuel cells, a device that generates electricity by a chemical reaction. There are different types and sizes of fuel cells, all designed in the search for greater efficiency ($\eta \approx 60\%$). Fuel cells, can be used to power vehicles which has an on-board electric motor."Fuel cells in vehicles create electricity to power an electric motor, generally using oxygen from the air and compressed hydrogen. A fuel cell vehicle that is fueled with hydrogen emits only water and heat, but no pollutants; therefore it is considered a zero-emissions vehicle."
Along the project the implementation possibility of three (3) hydrogen fuel cell autobuses in the city of Ilhéus- Bahia-Brazil is investigated - from the hydrogen production to the running and maintenance.The amount of buses was chosen based on the amount of hydrogen that one fueling station can dispenser per day -130 kg, so reducing the costs, too.
The project involves theoretically the following companies: Ballard, Hydrogenics, Tuttotrasporti, Marcopolo and New Flyer, it would have a costs of 8.762.830 euros for initial installation and a cost of 285343,7 euros per bus per year for maintenance and running, one ticket per passenger would cost 2,25 euros. Brazil is a country that is still in development; new technologies can create new jobs and contribute to the world renewable energies targets.

Key- words: *hydrogen fuel cell, sustainability, bus.*

1. INTRODUCTION

Ilhéus is a city located in the south of Bahia (a state in the northeast of Brazil), with latitude: 14º 47' 20" S and longitude: 39º 02' 58" W. It is near the cost and the economy is based on trade, tourism and small industries. 50,3% of the energy comes from oil and derivatives, 12,2% from hydropower, 14,8% from natural gas, 3,5% from sugar cane,10% from coal and others from non-renewable sources, the fuel for cars and public transportation are based in oil, there is no recycle policy for the garbage and others problems that does not contribute to a sustainable city.

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Furthermore, transport is the second biggest issuing of CO2 in the state, it consumes 17,6% of the energy given internal offer, what represents 50,9% usage of oil, derivatives and natural gas.

Therefore, in order to reduce the emissions of CO2, contribute to an energy transition and generate a more sustainable city, another solution to supply the transportation sector should be created. In this aspect, new technologies are of big importance.

A promising technology is fuel cells, a device that generates electricity by a chemical reaction. There are different types and sizes of fuel cells, all designed in the search for greater efficiency ($\eta \approx 60\%$). Fuel cells, can be used to power vehicles which has an on-board electric motor. “Fuel cells (Blomen, Leo, and Michael Mugerwa, 1993) in vehicles create electricity to power an electric motor, generally using oxygen from the air and compressed hydrogen. A fuel cell vehicle that is fueled with hydrogen emits only water and heat, but no pollutants; therefore it is considered a zero-emissions vehicle.”

In the above-cited city, the public transportation is made with buses and private cars, the buses are operated and maintained by a local business associated with the local government. As the public transportation plays a big role in Ilhéus, emitting tons of CO2 per year, the implementation of fuel cell vehicles (buses) can reduce the pollutants and contribute for a “greener city”.

Thereby, investigations on the possibilities of implanting fuel cell vehicles in a small city for public transportation and then in the state or country represents a way to reduce emissions of pollutants and contribute to a more sustainable world.

2. RESEARCH

The word *sustainability* comes from the junction of two words: sustain + ability, then it can be defined as the ability or capacity of something to sustain itself, remain and be maintained. In addition, the principle of long-term use and the direct and indirect environmental dependence are applied on sustainability. Everything we need for our survival and well-being is interconnected with nature. Being sustainable means that this relation can coexist with harmony, fulfilling social, economic, cultural, politics and ecology aspects without destroying the potential for people in the future to fulfill it too.

Thus, sustainability is important to make sure that we have and will continue to have food, electricity, energy, materials, and resources to protect humanity and our environment. If an activity is considered sustainable, it should be able to continue forever without any irreversible harm.

In the last years, the technology development associated with an improvement in human being lifestyle has increased the damage and pressure on natural systems. In most of the cities, there is no awareness about sustainability. In order to create an eco-city, the environmental impact must be taken into account and the population should be concerned about it, making efforts to minimize the pollution, CO_2 emission, and the need of energy, food, water and others.

In specific, a big problem worldwide is the air pollution, which carries significant risks for human health and the environment. “In 2013,((Joss, S. 2015) transportation contributed for more than half of the carbon monoxide and nitrogen oxides, and almost a quarter of the hydrocarbons emitted into the air in the United States of America.” Moreover, motor vehicles also emit pollutants gases, such as carbon dioxide, that contribute to global warming.

Thereby, generating and applying new and clean technologies for vehicles and fuel can significantly reduce air pollution and CO_2 emissions. A promising technology in this aspect is fuel cells.

This technology can be used in vehicles, such as buses. A fuel cell creates electricity to power up its electric motor, usually by using oxygen from the air and compressed hydrogen. A fuel cell vehicle that is fueled with hydrogen emits only water and heat as waste, therefore it is considered a zero-emissions vehicle.

Humphry Davy had effectively demonstrated the concept of a fuel cell in the early nineteenth century. William Grove, a chemist, physicist and lawyer, is generally credited by inventing it in 1839. The fuel cell is a device that converts chemical energy in electrical energy; it works like batteries but without needing recharges. While a battery holds a specific amount of energy within it, a fuel cell uses an external source of chemical energy and can run indefinitely, as long as it is supplied with a source of hydrogen and a source of oxygen.

A fuel cell consists of two electrodes a negative, (anode), and a positive one, (cathode) displayed like a sandwich around an electrolyte, and can run and produce electricity while there is fuel. Nevertheless, the system counts with a catalyst, which accelerates the reactions at the electrodes.

In a hydrogen fuel cell, the process can be described as it follows: the fuel (H_2) is fed to the anode and air (O_2) to the cathode. A catalyst at the anode separates hydrogen molecules into protons and electron, which take different paths to the cathode; the electrons go through an external circuit creating an electrical current flow; then, the protons migrate through the electrolyte to the cathode, where they unite with oxygen and the electrons to produce water and heat.

It has a high electricity production efficiency (up to 60%) and low emission of pollutants; the fuel is not combusted, the energy is released electro-catalytically. In a hydrogen fuel cell, the waste products are just water and heat and the last can be also harnessed for space heating, warm water or to drive refrigeration cycles. In addition, they are quiet during operation as they have just a few moving parts. However, before it gains a significant importance in the electrical power market, issues related to the choice of the fuel, its storage and alternative material in the fuel-cell stack should be solved.

The type of electrolyte used classifies the fuel cells. The electro-chemical reactions, temperature range and catalysts required will be determined by this classification. These characteristics affect the application for which these cells are most suitable.

The fuel cell bus sector has shown a significant growth, with more and more prototypes being released in Europe, Japan, Canada and the USA, but the high costs is still a barrier to widespread adoption. Moreover, the hydrogen storage onboard of the vehicle is another important challenge.

There are generally two classes of fuel cell bus architecture:

- Hybrid electric: which typically utilizes fuel cells as the main power and batteries for extra supply;
- Battery dominant: which uses the battery as the main power source and typically uses a relatively small fuel cell system.

Fuel cells in vehicles create electricity to power an electric motor, which generates mechanic energy to drive the automobile. They usually uses compressed hydrogen and oxygen from the air. A fuel cell bus usually uses a hydrogen fuel cell and sometimes have the power raised by batteries or a supercapacitor.

The propulsion process is: the hydrogen reserved at the tanks goes into the fuel cell where, through an electrochemical process, it generates electric energy. The waste product is only water. The electricity will turn the electric motor on, which generates mechanical energy to move the vehicle.

The hydrogen used as fuel; it can be produced by electrolysis, splitting water into its two components. Hydrogen is the lightest chemical element and offers the best energy to weight ratio of any fuel, but its low storage density is a drawback for storage. It is possible to store large amounts of hydrogen by compressing it to very high pressure and stock it in containers. Hydrogen has the highest energy content by weight of any fuel – 52,000 Btu per pound (33.6 kWh/kg) at 300 bar. For fuel economy comparison, the energy in one gallon of gasoline is roughly the equivalent to 1 kg of hydrogen. The energy density of a hydrogen gas (300 bar) is 33,6 kWh/kg, of petrol liquid is 13kWh/kg and natural gas 14kWh/kg.

Hydrogen can also be stored in solid state in chemical combination with other elements; the hydrogen is released from these compounds by heating them up or the addition of water.

The overview of the whole process can be described as it follows. First, an electrolyzer generates hydrogen using electric energy. Then, the hydrogen is compressed, purified and stored in tanks. This tanks supply the hydrogen fuel station where the bus will be refueled. This process is illustrated below by Fig.1.

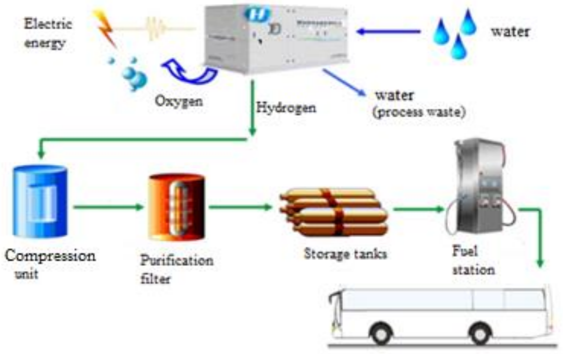

Figure 1. Fueling process overview

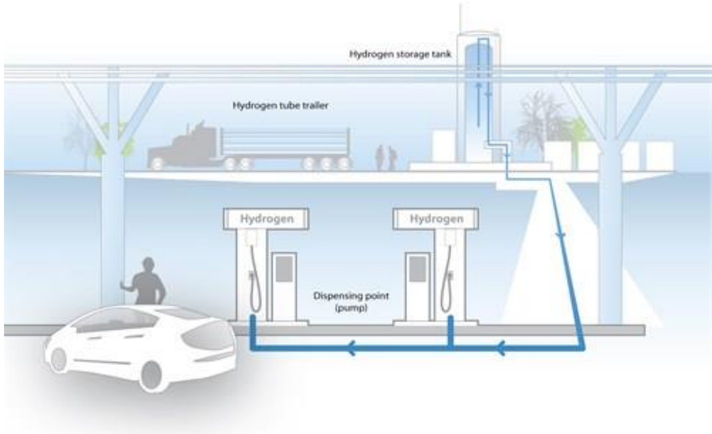

Figure 2. fuel station

A new fuel cell technology (Protonex ©,2016) is being developed for transport applications and portable fuel cell. This so called proton exchange membrane fuel cells (PEM) is replacing the traditional alkaline fuel cell technology. Proton exchange membrane fuel cells operate at low pressure and temperature ranges (50ºC to 80/100ºC), offer quick start-up times, require only hydrogen and oxygen to operate and have a special polymer electrolyte membrane.

The core of this system is composed by the bipolar plate (with the two electrodes- anode and cathode) and the membrane electrode assembly (MEA). The MEA consists of two porous electrodes that are layered upon either side of an electrolytic membrane. The bipolar plates are electrically conductive and facilitate the supply of oxygen and hydrogen to the MEA via integral flow passages. Importantly, the membrane must not be electrically conductive so the half reactions do not mix.

The process description is:

1) The hydrogen is delivered to the MEA at the anode side.
2) Catalyst split protons and electrons.
3) The newly formed protons permeate through the polymer electrolyte membrane to the cathode side.
4) The electrons travel along a load circuit to the cathode creating the current.
5) The oxygen is delivered to the cathode side of the MEA.
6) Oxygen molecules react with the protons and form water molecules.

The reaction at the anode is:

$H_2 \rightarrow 2H^+ + 2e^-$

The reaction at the cathode is:

$\frac{1}{2} O_2 + 2H^+ + 2e^- \rightarrow H_2O$

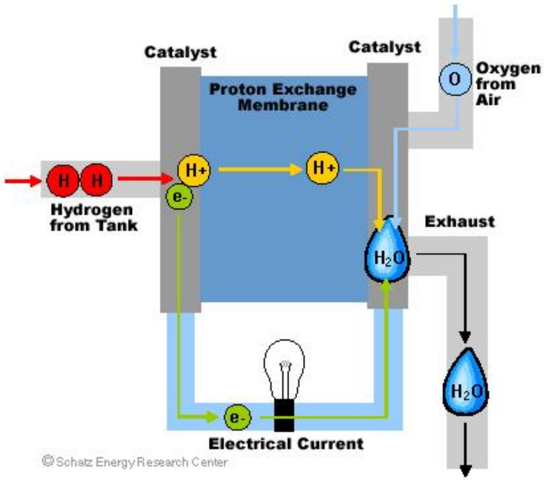

Figure 3. Fuel cell schematic view.

When applied in transportation, fuel cells can eliminate pollution caused by burning fossil fuels; if the hydrogen comes from electrolysis of water driven by renewable energy, then using fuel cells eliminates greenhouse gases over the whole cycle. The source of the electrical current plays a significant role in the process. If grid electricity is used, usually it has a carbon footprint associated. However, in Brazil the grid electricity comes mostly from hydropower, so a renewable source and the hydrogen is produced in a completely carbon-free way.

Electrolysis is a promising option for hydrogen production from renewable resources. The process, that takes place in a unit called electrolyzer, uses electricity to split water into its components (hydrogen and oxygen). An electrolyzer can be described as a reverse fuel cell, consisting of an anode and a cathode separated by an electrolyte.

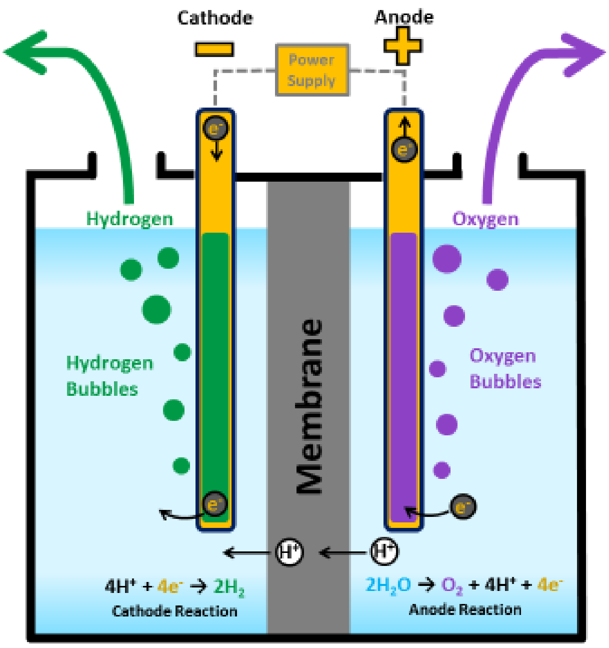

Figure 4. electrolyzer schematic overview.

2.1. Implementation procedures

Fuel cell autobus is a relatively new technology. Most of these buses are produced by UTC power, Toyota, Ballard, Hydrogenics and Proton Motor. The proton exchange membrane fuel cell can be designed, developed and manufactured by Ballard Power system, based in British Columbia, Canada, and can provide the fuel cell power plant, which is the prime power source for the bus.

In 2010, Ballard added the capability to manufacture the fuel cell systems for transit buses. The fuel cell system of this bus was one of the first systems manufactured at the U.S. facility.

This company also developed the fuel cell stacks for the projects: Brazilian hydrogen autobus, British Columbia transit fuel cell autobus in Canada and Transport for London. "Ballard (Ballard ®,2012) designs and manufactures fully- integrated FCvelocity- HD6 fuel cell modules delivering 75kW or 150kW of power for use in the bus market".

Ballard's 150-kW fuel cell incorporates the latest advances for durability and efficiency based on numerous field demonstrations of Ballard fuel cell-powered buses. The Ballard fuel cell has a 5-year, 12,000-hour warranty.

Marcopolo can manufacture the bus body and its components and Tuttotransporti can integrate the complete vehicle and manufacture the chassis. Moreover, New Flyer (a bus manufacturer in North America) technology and experts can be consulted.

According to Jeff Grant, from the market development of Ballard Power systems, the fuel cell module consumes approximately 7.2kg/hour at rated power 150 kW. A Norwegian comparative study of energy consumption and emissions characteristics of advanced buses in 2020 expects that PEM fuel cell hybrid electric buses will consume around 7MJ(1,944 kWh) per kilometer (Karl Verfondern,2007) ; thus 1,944 kW per 1 km in 1 hour; with the 150 kW it can move 77,16 km and consumes 7,2 kg. In the end, the bus can drive 154, 32 km with 14, 4 kg.

According to American Fuel Cell bus project – first analysis report, the FCvelocity- HD6 fuel cell fuel economy is 6,54 miles/kg, what means that it consumes 15 kg of hydrogen for each 157,8 km. Moreover, a project in Canada find out that " Overall (Brian D., James Andrew B. Spisak, 2012) the FCEBs(fuel cell energy buses) have an average fuel consumption of 15,48 kilograms of hydrogen per 100 kilometers."

Table 1: Fuel cell bus overview

Fuel cell bus overview	
Number of buses	3
Bus manufacture and model	Tuttotransporti + Marcopolo +New Flyer
Model year	2009
Length/width/height (foot/in/in)	40 / 102 / 140
Passenger capacity	37 seated or 31 seated with 2 wheelchairs; 19 standees
Fuel cell manufacture and model	Ballard- FCvelocity- HD6 fuel cell
Rated power (kW)	150

Hybrid type	Battery –lithium iron phosphate battery
Energy storage	A123, Nanophosphate Li-ion; 200 kW, 11 kWh
Fuel storage	Gaseous hydrogen, 8 Luxfer-Dynetek cylinders, 40 kg at 350 bar total.
Range(km)	Around 400
Bus purchase cost	Over $2 million

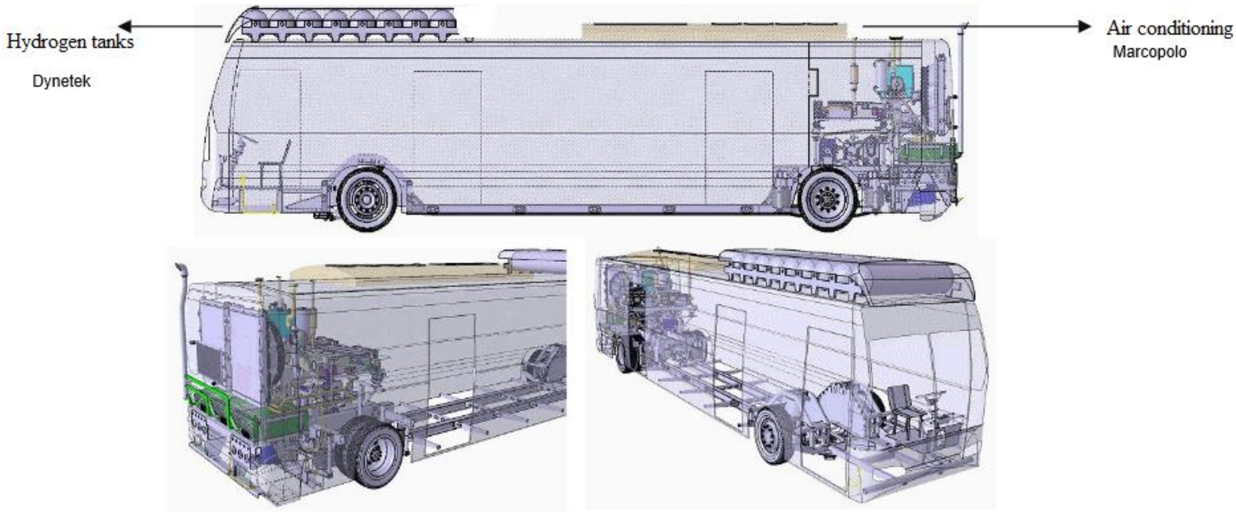

Figure 5. fuel cell autobus.

The U.S. Department of energy states that since 2002 the cost of automobile fuel cells had fallen 80% and that such fuel cells could potentially be manufactured for $51/kW. In the city of Vancouver, (Leslie Eudy, Chandler Battelle, 2013) for the 2010 Olympic games in British Columbia, 20 hydrogen fuel cell powered buses were added to the public transportation. These buses had a cost of $90 million, what means $4,5 million per bus .

In average, a fuel cell autobus costs over $2 million because they are now virtually hand made. A standard diesel bus costs about $400,000 and a standard hybrid costs about $550,000.

According to the BC Transit Fuel Cell bus project report, fueling 20 buses fleet requires a station capable of dispensing up to 800 kg of hydrogen per day when the entire fleet is operating.

The infrastructure for hydrogen refueling is a fundamental challenge. There is a cause- effect situation; the limited amount of hydrogen vehicles has inhibited the widespread of hydrogen refueling station, and vice versa.

Hydrogenics is a company well known worldwide and can be the manufacturer of the electrolyzer and hydrogen fueling station equipment. It offers complete hydrogen fueling stations with modular capacities from 20 kg to 130kg of hydrogen per day. The hydrogen is dispensed at 350 or 700 bar. The HySTAT^{TM} uses advanced electrolysis technology (Hydrogenics ©, 2013), using only electricity; it has a high efficiency < 65kWh/kg (350bar) or 68 kWh/kg at 700bar.

The station delivers an already pressurized hydrogen, eliminating the necessity of a compression station. Besides that, others advantages are: zero emission from production to fueling, no carbon footprint as the power comes from a renewable source (hydropower) and automatic, reliable and low maintenance system.

Table 2: Fueling station characteristics

Hydrogen production per day (kg)	130
Energy consumption (kWh/kg)	65
Pressure and storage (bar)	350

According to the American fuel cell bus project – first analysis report, a fueling station is used at least once daily to fill at least one hydrogen buses. The daily average use is 30 kg per bus.

As the station production per day is 130 kg and it generates 65kWh per kg of hydrogen, the total yield in a day is 8450 kWh or 704,2 kW(12 hours per day). Using the average daily use, the minimum consumption is 162,5 kW with the fueling station working 12 hours per day.

The hydropower Funil, located 124 km far from Ilhéus, has a power production of 30 000 kW. The system used to make available the energy generated is composed by a substation with nine (9) monophasic transformers of 4.800 kVA each, elevating the voltage from 6.600volts to 115.000 volts. At this point, there is a connection with the transmission system by the substation Funil II, located near the hydropower where the voltage is elevated to 230.000 volts.

2.2. Costs

In order to implement the project, provide and run the autobuses, some costs should be taken in account. First of all, the manufacture of the bus involves the following companies:

- Ballard
- Tuttotransporti
- Marcopolo
- New Flyer

Ballard will provide the fuel cell and the others will manufacture and assembly the bus. Cooperative teams are extremely important for the success of the project.

Subsequently, the fueling station, which will be provided by Hydrogenics, involves the electrolysis of the water until the dispensing of the hydrogen. Each bus will be fueled at least once per day. The research provided data for the hydrogen production costs from as low as \$4/kg to greater than \$26/kg. SunLine indicates that the best steady-state operating point for the reformer system would bring the average cost of hydrogen to around \$8/kg.

The water delivered to the fueling station should be distilled. For each kilomole of H_2, one kilomole of H_2O is used up. However, H_2O has a molecular mass 9 times larger than H_2, thus as 130 kg of hydrogen is produced per day, the amount of water consumed is 1170 kg per day. Each 5 kg of water costs €3,4 euros, thus 1 liter costs €0,70 of distilled water.

Moreover, there will be costs for maintenance and running the bus. The maintenance costs analysis includes:

- Cab, body, and accessories – includes body, glass, and paint repairs following accidents; cab and sheet metal repairs on seats and doors; and accessory repairs.
- Propulsion-related systems – repairs for exhaust, fuel, engine, electric motors, fuel cell modules, propulsion control, non-lighting electrical (charging, cranking, and ignition), air intake, cooling, and transmission.
- Preventive maintenance inspections (PMI) – labor for inspections during preventive maintenance.
- Brakes
- Frame, steering, and suspension
- Heating, ventilation, and air conditioning (HVAC)
- Lighting
- Air system, general
- Axles, wheels, and drive shaft
- Tires

Based on fuel cell buses reports, the following estimation is for 1 year of operation. Total maintenance costs include the price of parts and labor rates at €5 per hour; they do not include warranty costs.

$$\text{Cost per km} = [(\text{labor hours} \times 5) + \text{parts cost}] / \text{Kilometers} \tag{1}$$

Considering that the line that the bus will operate drives 40 km per hour, the workday hours will be: from 6a.m – 10 a.m. and from 18 p.m. – 22 p.m. on a workday it will be 320 km, what is 116.800 km per year, thus the average velocity of the bus is 40 km/h. It is estimated a budget of € 1500 for the parts costs and labor hours around 300. Cost per kilometer = € 0,026

For running the bus, it is important to consider the fuel cost and the bus driver salary. Considering the bus driver rate is €7 per hour and as the bus will run 2920 hours per year, the costs with one conductor will be € 20440 per year. Moreover, the first analysis of the American fuel cell bus project found a fuel costs of (\$0,76 per km approximately € 0,71 per km).

In addition, the company Hydrogenics will install the hydrogen fueling station. According to National renewable energy laboratory, significant costs reductions (Leslie Eudy, Chandler Battelle, 2013) will be achieved by 2014-1016; on a capacity basis, the capital cost is €5867,9 per kg/day of station capacity, value that multiplied by the total amount of hydrogen kg/day gives the capital cost of a fueling station.

Table 3: Installation costs

Number of buses	3
Bus production + project (€)	2.000.000
Complete bus with fuel cell (€)	2.000.000
Fueling station (€)	762.830
Total installation (€)	8.762.830

The fix cost per bus is €4.762.830, each extra bus would add € 2.000.000 to the project.

Table 4: Maintenance and running costs per year

Number of buses	3
Total of km driven per bus (km)	116.800
Fuel cost (€/km)	0,71
H_2 production cost (€/kg)	7,54
H_2 needed per bus (kg)	10898,9
Maintenance (€)	9.000
Fuel production costs(€)	246.533
Water (€)	290.394
Three buses conductors (€)	61.320
Fuel costs (€)	248.784
Total (€)	856.031

The value calculated above is for three buses, thus the total maintenance and running costs per bus per year is €285343,7.

2.3. Expected results

If the hypothetical implementation became a reality, some consequences in the city and citizens life can be expected:

- Scientific impact: the project would cause the necessity of studies about the utilization and fabrication of the hydrogen as a fuel, encouraging universities and companies to engage in an energy transition challenge.
- Technological impact: the development of hydrogen fuel cells and electrolyzers production can create a supply chain in this area.
- Economic impact: it is possible to expect generation of jobs opportunities for technical experts, reduction of fuel cell costs, reduction of fuel cell buses production and public revenue increment. On the other hand, the running and maintenance costs will be subsidized by the population and the ticket will be more expensive than the usual one
- Social impact: beyond the direct impacts as jobs generation, encouraging research, the greatest impact to be verified is the improvement in the public transportation quality because of the utilization of vehicles technologically advanced and health quality.
- Environmental impact: emission reduction of gases that causes greenhouse effect, diminishment of noises and emission reduction of pollutants.

3. BUSINESS MODEL

The Business Model Canvas, is a strategic management and entrepreneurial tool. It allows describing, designing, challenging and inventing a business model. In this project, it is important to give an overview of the hypothetical implementation plan.

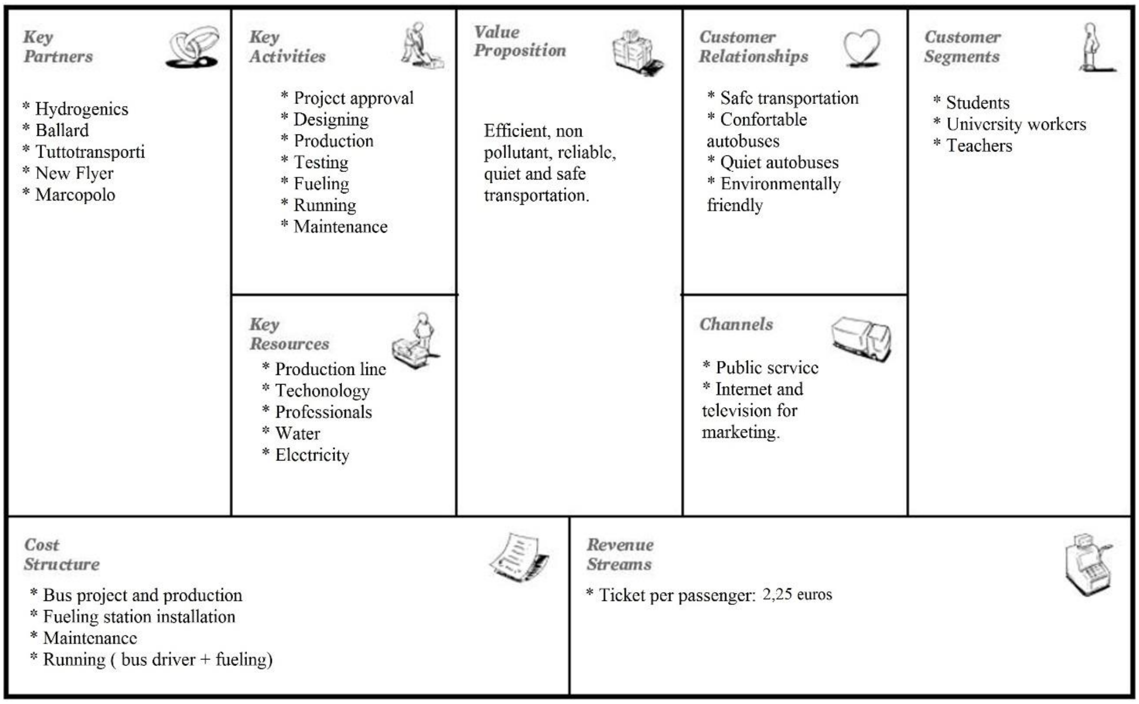

Figure 6. Canvas model

4. RECOMENDATION

The amount of fuel cell autobuses chosen was based in the amount of hydrogen that a single fueling station can dispenser. For a future research, it would be relevant, study the possible substitution of the whole bus fleet for fuel cell autobuses or combine new fuel technologies as biodiesel, ethanol, sugar cane and hydrogen or even a gradually substitution of the fleet. This way, the costs could be reduced and more knowledge and technology would be acquired.

5. CONCLUSION

The global urbanization and population growth is increasing the demand for public transportation, each year. At the same time, the growing need for renewable energy in the search of a sustainable world and reduce the CO2 and pollutants emissions is creating a new way of meeting the demand needs.

Fuel cells are a promising technology in this aspect, because there is no combustion, fuel is converted to electricity more efficiently than any other electrical generating technology available today.

Every technology has its disadvantages, “experts say (Wired News, 2008) it will be 40 years or more before hydrogen has any meaningful impact on gasoline consumption or global warming, and we can’t afford to wait that long’’. In 2014, Joseph Romm stated that fuel cell vehicles still have not overcome the high costs of producing hydrogen vehicles and fueling; fuel cells are still very expensive. With the implementation of autobuses in the city of Ilhéus, the public government would spend at least € 8.762.830.

Another challenge is the lack of infrastructure. Fueling stations need to invest in the ability to refuel hydrogen tanks for the vehicles become practical, but with so few customers on the road, it is improbable that they will invest in it. The on-board storage is another big issue; hydrogen is a very flammable gas and has a low density compared to gasoline, thus a tank is currently too large. In addition, the tanks needs robustness, many are sensitive to temperature and contamination. Moreover, it can become irrelevant if batteries got good enough.

In what concerns to this project, there are a few challenges that must be overcame. First of all, most of the companies involved (Ballard, Hydrogenics) are not situated in Brazil and also don’t have a branch there. Second, Ilhéus is a small city with a limited budget and only a few people really interested in energy transition. Moreover, there would be needed financing and investors.

Hydrogen fuel buses are the most comparable in operation to conventional buses, with high driving performance and route flexibility. Although the initial costs are higher, the maintenance and fueling costs are lower before adding any of the environmental benefits.

Moreover, fuel cell usually aren’t applied in normal cars because of the tanks size, from this perspective, bus are a logical application as it can store larger volumes; also, the high annual mileage of a bus means that the additional capital cost may be recuperated quickly.

In addition, there are no moving parts in a fuel cell stack, making them more reliable and quieter than generators, and unlike batteries that must be disposed of once their chemicals are used up, fuel cell reactions do not degrade over time and can theoretically provide continuous electricity

According to the University of São Paulo (USP), the low air quality spends around €800 millions of the brazilian public money, each year. Mostly with deaths and treatment of diseases associated directly or indirectly with the pollution. Furthermore, it is estimated that the bus fleet in São Paulo releases more than 1.5 million tons of carbon dioxide per year.

Another clear advantage for the population and the environment is the pollutants and CO2 emissions reduction. "A typical bus releases between 822g/km to 1,3 kg/km (Loyselle, Patricia; Prokopius, Kevin, 2011)", the bus fleet in Ilhéus is composed by 73 vehicles. Considering that each of them drive only 320 Km per day, it is 416 kg per day, what in a year is 152t of CO2 emitted. The installation of one (1) fuel cell autobus would avoid this emission, considering that the hydrogen is produced by a clean source and that the fuel cell has as waste only water.

"Ballard's (Ballard ®,2012) sixth generation FCvelocity®-HD6 modules powered the fuel cell 20-bus fleet operated by BC Transit in Whistler, British Columbia until March 2014, reducing greenhouse gas emissions by approximately 1,800 tons per year."

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7. AUTHORIAL RESPONSABILITY

The author is the only responsible for the content of this paper report.