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Research Article

Gaia Project: Construction of a Cold Plasma Reactor to Pyrolysis of Methane in order to Treat Brackish Water for Production of Hydroponic Resources

Sena André Pedral S de[1]* and LIMA Jr Ailton de SS[2]

[1]NDTA, Development Center of Advanced Technology, Rua Ten Fernando Tuy, Brazil

[2]Department of Mechanical Engineering, DEM, Polytechnic School, EPUFBA, Federal University of Bahia, UFBa - Rua Aristides Novis, Brazil

***Corresponding Author:** Sena André Pedral S de, NDTA, Development Center of Advanced Technology, Rua Ten Fernando Tuy, Brazil.

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Abstract

Increasing lack of water recognized for the diverse needs and purposes of humanity. In addition, it is aware that, due to its irregular availability, which varies markedly throughout the year, from year to year and from region to region, the use of water in a continuous and indefinite way becomes impossible. Therefore, one of the strategic goals for preserving the availability and quality of water resources is to establish adequate use criteria in all productive activities, which is why this work began to address the issue of water scarcity, based on information and studies that can build a system that directs and optimizes natural resources. The proposed technological models should consider a strict balance between agricultural production and natural resources preservation, guaranteeing feedback and waste treatment. The current development of irrigation and hydroponics depends on technological and economic procedures to optimize water use, improve application efficiency, provide productivity gains based on crop response to the application of water and other inputs, without compromising availability and quality of the resource. Therefore, the NDTA joined the need with the ability to change or adapt and thus the GAIA project built. Which combines two projects: first, the miniaturization of the CHIRON Project, which provides for the rational and intelligent use of brackish water, for producing pure water and cogeneration of energy, from a plasma reactor for pyrolysis of CH_4. The H_2 produced in the reactor will used to heat-treat brackish water, generating steam, which will be used for power generation, without affecting the environment and having by-products of the process the generation of clean energy, the production of H_2 and C, yolk salt and demineralized and deionized water. Secondly, the DEMETER project that developed a hydroponic bench, in a closed circuit system and reuse of water for food and energy production, which will be generated from the waste water used in the benches, which will be reprocessed in a thermal treatment unit, which will recover part of the fertilizer and make the water again demineralized and deionized.

Keywords: Brackish Water; CHIRON Project; CH_4; H_2; Hydroponic Bench

Introduction

Water is a natural resource indispensable to the survival of man and other living beings on the planet. It is a fundamental substance for the ecosystems of nature, a universal and important solvent for the absorption of nutrients from the soil by the plants, and its high surface tension makes possible the formation of capillary fringes in the soil. Besides being essential to the atmospheric water formations, influencing the climate of the regions; to the human, is responsible for approximately three quarters of its constitution. Unfortunately, this natural resource increasingly limited and exhausted by the impact of man's actions on river basins, degrading their quality and damaging ecosystems [15].

The water reality, especially in aspects related to the supply and use of water, is a topic that has historically marked the discussions on regions with low rainfall. These concerns have focused on the studies of recent years and the efforts of their researchers have focused on the search for an understanding of the correlation between the water of these regions and their socioeconomic indicators. For water, scarcity seriously affects the population, generating misery due to the loss of productive capacity, because of environmental degradation [14,18,19].

Irregularity and low rainfall rates coupled with high evapotranspiration rates and the geological formation of semi-arid regions favor surface water scarcity and disadvantage the implementation of conventional agricultural production systems as they require large amounts of water [3,9].

Known as a scarce natural good, water has become a product that too coveted by the population that inhabits the arid boundaries, especially when its access becomes more problematic in the occurrence of droughts. This water shortage and the increasing demands and competition between the different uses highlight the importance of adequate management of water resources [2].

In the field of agricultural production, water is a more limiting resource to its growth and development, since it is associated to the fact that almost all the physiological processes of the plants. They influenced, direct or indirectly, by the water supply. Faced with the quest for expanding food production, climate change and the water crisis in the world. It would be necessary to increase agricultural production and at the same time reduce water consumption in agriculture, which leads to the dilemma of irrigated agriculture and hydroponics, which are practices that aim to improve and increase productivity, but which can be one of the main forms of environmental degradation [14,15].

The need to expand agricultural production in order to meet growing human needs has increased the pressure for new productive areas, increasing irrigation in semi-arid regions, which allows a differentiated control over natural conditions, making production feasible during the year. However, irrigated agriculture and hydroponics in the region is limited, due to the low density of rivers and high evaporation rates, making it difficult to use dammed water. To cope with this shortage, there is increasing pressure on alternative sources, especially underground reservoirs, fossil water, which can be exploited to meet water demand [1,15,21].

However, groundwater may have a limiting chemical quality (concentration of dissolved salts) and its use could pose risks to the environment, promoting salinization of the soil and, as a consequence, damage to the agricultural production itself. Therefore, the exploitation of brackish water will only be justified if there is sufficient technology available to farmers to deal with brackish waters, whether directly using their crops or via desalination to obtain fresh water. Another limitation to extensive agriculture in the region, with these waters, concerns the reduced flow of many wells already drilled [3,7,10,15].

Many researches carried out to promote a suitable destination for brackish waters in agriculture, but they usually simulate the use of these waters in conventional farming, which in most cases results in reductions in productivity and negative environmental impacts. New cultivation alternatives for the use of these waters are little studied.

In this context, hydroponic systems may be more suited to the characteristics of semi-arid regions than conventional soil-based cropping systems under irrigation or not. In summary, the following comparative advantages achieved:

a) For the same level of fertility and salinity of the medium, plants may be more stressed in conventional crops than in hydroponic crops, considering that in conventional cultivation, the level of humidity oscillates between one irrigation event and another, with a decrease in potentials osmotic and matric in the total potential of water. In hydroponics, the matric potential does not exist, at least most of the time, due to the state of saturation to which the plants are submitted, a fact that can be an advantage when using brackish water;
b) The greater potential of water in hydroponics should represent a greater absorption of water and nutrients by plants, with lower energy expenditure and lower morphophysiological losses, for the same amount of salts, in relation to soil cultivation. Maintaining the equivalent state of saturation in the soil, although feasible, entails incurring greater phytosanitary risks, being an epidemiological condition for pathogens many times already present in the environment, besides representing greater chances of ion leaching, with financial losses (fertilizer ions) and or environmental (pollution of soil and receiving waters). In this sense, in hydroponic systems, crops, especially fast-growing crops, are expected to provide sustainable use of brackish, natural or residual waters from desalination;
c) In the conventional systems, changes in soil structure verified, mainly in function of the Na^+ ion, which consequently causes damage to the plants. In hydroponics, these effects become null or smaller, because in this system there is no effect of salinity on the matrix, being a factor that would contribute to the use of brackish water in hydroponics;
d) At the end of the cycle, whether in soil or in NFT hydroponics, the contribution of essential and non-essential elements

to the plants carried out in the growing medium. In both farming systems, there are pollutant load even salts. In soil cultivation, the natural drainage associated with the leaching fraction can remove this charge, but the removal leads to the groundwater, contaminating them. When underground drains installed, the pollutant load can collect and emitted out of the culture medium, but usually the emission takes them to bodies of water or terrain, creating an environmental degradation. In NTP hydroponics, the pollutant load already captured and, with the advantage that it can be less toxic than soil leaching, it can dilute for recirculation, used to irrigate other crops, or even be easily concentrated in evaporation tanks. However, they may contain biological contaminations that are released into the environment and may migrate to groundwater contaminating groundwater [3,9,14,15,21].

It was from this scenario, from agricultural water needs, stress from drinking water sources and climate change, which the GAIA project emerged (see Figure 01), emerges from the merger of two projects produced by the NDTA, which unite the need for produce food with the green generation of energy and use of brackish water, which are:

- **Chiron Project:** that uses the reform of CH_4, produced from the decomposition of urban waste, for the desalination of brackish water with energy generation;
- **Demeter Project:** which builds a hydroponic production system associated with a thermal treatment system for wastewater and biodigesters.

Figure 1: Infographics of the GAIA Project.

Source: Author

Water resources

According to Sena*., et al*. (2016), concerns about environmental conditions reach segments of the social, political and economic sphere, at a time when environmental problems require reflection on the use of natural resources in all industrialized and developing countries. It is no longer a secret that the planet's water resources gradually depleted and that. In addition to the pollution of rivers and springs, irresponsible consumption and without sustainable rationale in economic development is a relevant factor in water reduction.

There has never been so much discussion in environmental management, in the preservation of nature, nor was it sought to educate humanity to look back and take examples of their own mistakes; however, potable water on the planet continues to decline. What can mankind expect in the unfolding of this fact? What are the perspectives of reversing this situation? What is the individual's responsibility as the protagonist of a story in which he destroys his own sources of life? [15,20].

These issues should burn in the consciousness of millions of people just as it will burn in each other's pockets, at a time when the water will cost too much to pay. The tendency is for capitalism to be guided by a primary competitiveness - that of maintenance - when companies recognized as ethical and responsible will have preference in the choice of buyers and consumers [15].

Data on the availability of water in the world are widely known: although the planet is 70% water, most of it (97% of the total) made up of oceans and seas and is unfit for human consumption. Of the remaining 3%, 69.8% are in glaciers, 29% in aquifers (some with no easy access), 0.9% in other compositions and only 0.3% in rivers and lakes [1,2,10,11].

In view of these numbers and the successive effects of anthropogenic action on the natural environment, the availability of water increasingly reduced in several parts of the world, which causes entire areas to face the total or partial shortage of this resource. For this reason, the big question is what causes water scarcity? The enumeration of factors may indicate possible solutions to taken to combat this problem:

Growing consumption

The increase in water consumption in the world has contributed to a reduction in the availability of water resources. Although water has a cyclical renewal capacity, the increase in consumption may be greater than this natural replacement, generating scarcity. This picture is characteristic of several parts of the world - including some regions of Brazil - and called water stress. The causes for the increase of water consumption are several:

a) Population growth,

b) Economic development and

c) Increased production in peripheral or emerging economies, increased production activities, increased consumption of products that use a lot of water in their production, among others.

Pollution and degradation of water reserves

The human being, in most of his activities, needs fresh water to guarantee his subsistence. Even so, many anthropogenic activities contribute to the decrease of this water, mainly with the pollution of rivers and springs, that become unusable in a short period. One of the most frequent ways in which this happens is the pollution generated by the deposition of sewage or by the excessive pollution of the cities. In places where environmental basic sanitation is not adequate, this situation becomes even more dramatic. In aquifers and underground reserves, soil pollution often leads to intoxication of the water table, affecting the obtaining of mineral water. Therefore, the conservation of some water reserves also depends on the maintenance of the soils and their non-pollution, which leads us to the next topic.

Degradation of natural resources

It is not only the degradation of water and its reserves that affects water availability. Nature, after all, functions from an equilibrium, and its alteration causes a series of chain effects. Pollution or soil erosion, as already mentioned above, affects underground reserves and even surface waters. In addition, many rivers suffer from the erosion of their banks, caused by the removal of their riparian forests, responsible for precisely preventing the advance of the process in question, which generates a greater deposition of sediments in the riverbed, causing the silting. Over time, the affected rivers cease to exist or decrease considerably the flow of their waters. The destruction of forests with burning and deforestation are also a problem in this area. The vegetation has the function of preserving springs of great rivers and provide, in some cases, humidity to the atmosphere, which causes the rains. With the decrease of the vegetation cover around the world, the water gradually becomes scarcer.

Climate change

Climate change - although it is not a consensus in the scientific community - is causing rising temperatures on Earth, because of pollution and intensification of the greenhouse effect, which characterizes global warming. Thus, although the volume of water on the planet is always the same, the water cycle is occurring at a lower frequency, causing severe droughts and making water shortage a chronic problem. However, it is always dangerous to associate any drought or water crisis with climate change without conducting studies and the existence of specific prior knowledge. Therefore, scientific research is always important to provide us with accurate information in order to avoid hasty conclusions. It is worth remembering that climate change is a controversial subject even among experts in the field.

Lack of basic infrastructures

Water scarcity becomes a problem even in countries or localities around the world that have a certain water supply. This is due to economic issues, especially in peripheral countries, where problems related to lack of resources affect investments in water abstraction, storage and distribution systems for the population and productive activities [1-3,9-12,19,20].

It is clear that these factors listed above are those that cause water scarcity in regions where there was no such problem or where it could be easily solved, which does not include areas where there is physical water scarcity, such as arid and desert In order to combat water scarcity. It is, therefore necessary, to identify problems with solutions analysis, which may include the adoption of alternative supply systems, water reuse, river transposition, sea water desalination and many others.

According to surveys in ANA (2017); Sena (2016); Loucks and Beek (2017), there is water available to meet the needs of the world population. Although differences in consumption are directly proportional to socioeconomic development, confirming that maintaining a reasonable quality of life requires 80 liters of water per day for each inhabitant, although the average consumption can vary from the 25 liters daily of an Indian family to the 500 liters of a North American family. According to ANA (2017), scientists and researchers estimate that between 0.7% and 2% of the entire volume of fresh water is available for use in agriculture, industry, services and for human consumption.

In the approach to the process of water maintenance on the planet, it observed that: The interest of economists for water comes from many decades. Overlooking the sources of natural resources and riches, many economic scientists have devoted themselves to scaling scarcity and calculating the impact of uncontrolled exploitation of reserves [16].

Worldwide, new technologies allow the controlled deceleration of dangerously rapid consumption of these finite resources but can create serious risks such as new types of pollution and the emergence of new varieties of life forms that would change the course of evolution. Meanwhile, industries that rely heavily on the environment and pollute more rapidly.

It understood that the same concern raised in science and education, also applies to governments, businesspersons, industrialists, economic managers and society in general, as water becomes a product of export, especially by Brazil, composing indirectly the products marketed.

Agriculture seen as the human activity that the most consumes potable water and, together with livestock and steel, allows the country to be interpreted as a major exporter of water, with almost 95% of Brazilian exports based on economic activities that depend on water [15]. The data presented by ANA (2017) demonstrate, when analyzing the soybean production cycle, it has been: The plant requires 500 to 700 mm^3 of water during the whole cycle, resulting in 2 liters of water for each gram of soybeans.

Not only is soybean a major consumer of water, if we check other agricultural crops, it is observed that the production of each kg of corn requires 1.6 m^3 of water, as well as 2.4 m^3 for each kg of rubber and 1,1 m^3 for each kg of irrigated rice. Thus, while agriculture consumes 73% of the water available on the planet, taking into account irrigation needs, industry consumes 22% of the total and domestic use only 5% [1,2,11].

Thus, all agricultural activities only develop with the presence of water, which causes the water to stop being seen as a natural resource and become a commodity, subject to availability or scarcity. The complex of water resources today is directly related to profit, as well as the attraction of investments, productivity; water already has a price defined according to the rules of the law of supply and demand, obeying market rules: its value is higher where reserves are lower [14,15].

Water is vital for life and a basic requirement for the development of countries. However, it observed that on the planet, the human being still does not have assured and quality access to water in order to meet their most basic needs. Water resources and related ecosystems that provide and sustain them are under threat of pollution, greenhouse effect, unsustainable uses, land-use change, climate change and many other forces. The link between these threats and poverty is clear, so the poor are the first and most severely affected. This leads to one simple conclusion: economic practices of climate and water resource degradation are not an option. There is certainly a huge diversity of needs and situations around the world, but we all have a common goal: to provide for the continuity of water resources in the coming years. This will impose on governments and society, the protection and recovery of rivers, lakes and related ecosystems; promoting sustainable development and political stability, ensuring that each person has access to sufficient water, at an acceptable cost, to lead a healthy and productive life, and that the vulnerable is protected from the risks related to health hazards.

Hydropony

The hydroponic production of vegetables, greens and vegetables has been gaining more and more space due to the best use of the area, precocity at harvest, more efficient use of nutrients, better quality of the product, also allowing the control of environmental factors, which limit their cultivation at certain times of the year [7,15].

Hydroponics is a technique of plant production in which the soil replaced by a nutrient solution composed of water and mineral elements. For this project, the most commonly used seasonings in the Bahia' cuisine, chives (*Allium schoenoprasum*), parsley (*Petroselinum crispum*) and coriander (*Coriandrum sativum)* used for the NFT technique, since it has a great appeal for consumption among the population. In it, the nutrient solution flows through the cultivation channels, where the roots housed, irrigating them and supplying oxygen and nutrients to the plants. The basic structure for this cropping system is the nutrient solution tank, motor-pump assembly, nutrient solution in the distribution pipeline, cultivation channels, collector piping and timer.

Contrary to popular belief, hydroponic plant cultivation is an ancient cultivation technique. The growth of aquatic plants in the oceans predates their growth on land. Ancient hieroglyphic archives dating from hundreds of years before Christ describe the growth of plants in the water along the Nile River. Rice has grown in water since time immemorial in China. Many believe that, as a cultivation tool, hydroponics began in ancient Babylon, in the famous hanging gardens, considered one of the seven wonders of the ancient world.

The commercial cultivation of vegetables using hydroponic techniques is a very recent practice, and has been expanding very slowly, approximately, the large urban centers of the Brazilian Northeast. Where arable land is scarce and expensive and where there is great demand for vegetables. In such regions, the production of vegetables mostly carried out under protected cultivation, in which case hydroponic cultivation presents itself as an advantageous alternative. The shorter production cycles, the possibility of using vertical space in the greenhouse, higher productivity, lower labor requirements, lower risks of salinization of the cultivation medium and pollution of the groundwater with nitrate are among the main advantages of hydroponics [14-16].

Hydroponic crops are generally referred to as plant nutrition by means of an aqueous solution containing all essential elements for growth in defined quantities and proportions and free of high amounts of potentially toxic elements [14-16].

Hydroponic crops can be grown in aerated nutrient solutions without the presence of any kind of substrate, or using chemically-less substrates such as sand, gravel and expanded clay to give adequate support to the plants [12,14-16,20].

The nutrient solution can supply by continuous or intermittent flow (NFT), sub-irrigation, or drip irrigation. The use of sub-irrigation and dripping is not very expressive. Thus, the nutrient solution is the most important factor in hydroponics, its correct management will reflect in a good development of the culture. Therefore, it should be prepared so that it meets all the nutritional requirements of the vegetable. These requirements vary according to plant and formulated according to nutrition studies, which take into account the species, stage of growth, temperature and light intensity. For this reason, technical support is required for beginners for the specific formulation. Water-soluble fertilizer salts in the form of macro and micronutrients should be used [7,15,20].

The use of hydroponics has expanded in recent years as a way to increase production. Several factors contribute to this promising business, as hydroponics presents a series of advantages such as production in small areas, use of low amounts of water and fertilizers, reduction in the number of operations during the crop cycle, harvest anticipation and drastic reduction of agricultural pesticides. The production is of good quality, with no or almost no use of poisons.

In addition to all the advantages presented it observed that for hydroponic system implantation a producer will have a high cost, since he will have to acquire special materials and equipment:

- As generators, because he could be at the mercy of lack of energy;
- Sophisticated automation systems among others, which makes the project impossible to generate income in low-income communities.

Gaia Project

Today, there is a crisis of water resources, especially in semi-arid regions. The pressure on water supply emerges from the disorderly growth of the world's population, coupled with the intensified demands of agricultural and industrial needs, which destroys and makes water reserves unviable, increasing demand on salinized systems. What is the problem? Due to the salinity of the water, it becomes unsuitable for living things. Thus, most of the available water does not have adequate quality for potability and agricultural or industrial demands [1,8,13].

This water shortage has pressured many cities to explore the use of alternative sources such as brackish water. This implies compliance with legal regulations for the disposal of filtering waste, established by environmental agencies [8].

Therefore, Gaia Project must meet the 8 guidelines for water use and treatment established by ANA (2015):

- Work in association with reverse osmosis desalination systems, existing or not, using salt water for the water production process that meets economic activities;
- Do not interfere in the local structure of capture and treatment of drinking water for the human population;
- Create conditions for the improvement of local income and improve the living conditions of the region where the project is implemented;
- Control water consumption to avoid reducing the availability of water resources;
- To guarantee the continuous evolution of the project, in order to meet new demands and productive needs;
- Contribute to reducing drinking water consumption, economic activities and increasing the availability of electric energy;
- Construct integrated company-school systems for preparation and training of local labor to be used in the project; and,
- Do not emit contaminant residues, whether liquid, solid and / or gaseous, and mainly greenhouse gases [15].

Based on these points, the GAIA PROJECT is the association of two projects of the APOLLO Research Group; they are CHIRON and DEMETER. This procedure united three elements the production of water and energy, with the production of food based on a system of clean production. With this conception, one can join the projects as shown in figure 2, and the construction of the GAIA project has the following bases:

- Chiron Project: It based on the rational and intelligent use of brackish water from wells, having any content of dissolved solutes and contaminants, for the purpose of producing energy through a plasma reactor for pyrolysis of CH_4, using a modular and interchangeable structure for the generation of Colloidal Carbon and Hydrogen. H_2 will feed a desalination reactor, generating superheated steam. This drives a turbogenerator of electric energy, without affecting the environment and having as byproducts of the process the generation of clean energy, the production of H_2 and C, gem salt and pure water; and
- Demeter Project: Developed a system of closed-circuit hydroponics, for water consumption and waste generation, for the production of several plants in a clean way. Thus, the structure of the benches was incorporated, two reactors for waste treatment. The first to treat wastewater from irrigation plants, which through the burning of the H_2 generates superheated steam; which will be sent to an electric power generator. This process not affecting the environment and having as by-products of the process energy, fertilizer residues, pure water, and the second takes advantage of the entire organic residue from the plantation by sending them to biodigesters to generate biogas for the CH_4 pyrolysis reactor (see Figure 2).

In view of these premises, the GAIA project seeks to meet the main characteristics of NDTA projects, that is, to have a simple automation in their constructive characteristics, guaranteeing their interchangeability and maintenance, as well as their low automation costs. In addition, the units of the GAIA Project were designed and developed in modular systems, proto-units, to be placed in reduced and limited physical spaces, based on their constructive concept. Thus, it can expand its productive capacity according to the needs.

Chiron Project

The process of treating brackish water is a complicated process, because the salts have a strong bond with the H_2O molecules, rendering various conventional water treatment procedures inefficient. Therefore, it is necessary, the use of thermal processes capable of breaking the forces of attraction between molecules. Thus, the CHIRON project uses a thermal system to remove the salts [15-22].

Figure 2: Process Flowchart.

Source: Sena., *et al.* 2016

Unit 01 – Plasma Reactor for CH4 Pyrolysis

The reactor designed for the production of colloidal carbon and hydrogen through thermal plasma, although using electric energy and an inert gas in the process has several advantages in its application that are compensatory, for example: increased efficiency, reduced reaction, low cost of the equipment, favoring, variety of productive size and making possible its industrial application. The reactor uses a noble gas as plasmogenic, avoiding the formation of CO_2 [16-22].

Another important factor is that the plasma process allowed the use of different sources of raw material, besides methane gas, butane, propane, acetylene among others, but it decided to use biogas. Thus, the production of hydrogen as an energy source and that of colloidal carbon, as an industrial input, becomes attractive and compensates the energy and operational expenditure of the system [16,22].

The Plasma System

The plasma system is composed of an untransformed arc plasma torch and a pyrolysis chamber, designed to hold the heat from the plasma jet to the maximum. The plasma jet formation occurs between the cathode and the anode (cooled by the system's own water), so the gas is heated, ionized and emerges from the torch, like a plasma jet. The gas to be degraded CH_4 was introduced into the pyrolysis chamber with controlled flow, coming into contact with the plasma and undergoing degradation [12,16-22].

The Process

The decomposition of CH_4 for hydrogen and colloidal carbon production is quite promising if added to other activities using its by-products. Because the conversion of CH_4 is endothermic, the thermal plasma is very efficient, because in these conditions, high temperatures and high degree of ionization, the chemical reactions accelerated through the energy supply, in addition, there is no emission of CO_2 or other gases since the system did not oxygenate (see Figure 3).

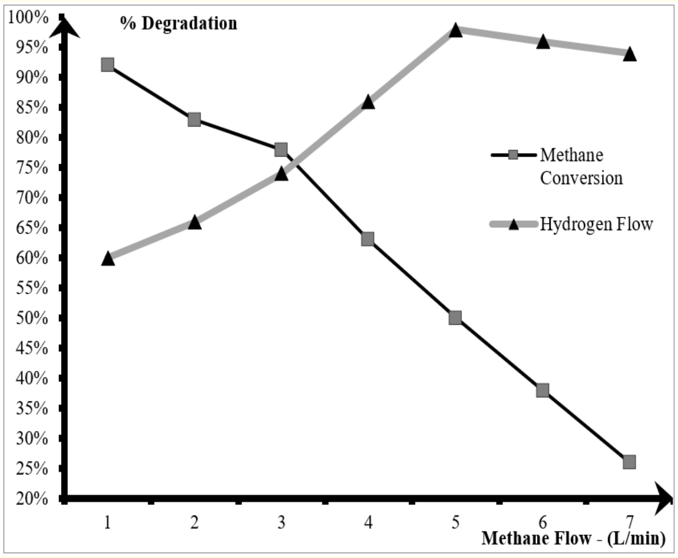

Figure 3: Conversion% of CH_4 (■) and yield of H_2 (▲) in different flows of CH4.

Source: Sena (2016)

The use of UNIT 01 plasma pyrolysis reactor has several advantages, such as the high energy density in the plasma that allows the construction of a compact reactor. Due to the characteristics of the plasma, it is possible that the flow is continuous, allowing the formation of carbonaceous materials of different qualities without pollution and providing two commercial products (H_2 and C), both with high purity.

The plasma pyrolysis of CH_4 does not produce CO or CO_2, because the carbon in the CH_4 molecule does not react with the oxygen element because it does not exist in the process. What occurs in the process is breaking the molecule, resulting in isolated carbon in its solid form. The H_2 and C molecule are products of this process. The process enables a simple purification of hydrogen, since the solid carbon can extract from the stream by physical separation. In relation to steam reform, it has shown to be more efficient in the contribution of greenhouse mitigation, which depends on how the energy (heat) needed to crack the hydrocarbon, obtained and how the carbon will be harnessed.

Unit 02 – Desalination Thermal Reactor

Since the sixteenth century, the desalination of seawater used in vessels. The desalination began in the 18th century and began to play an important role in the late 40s and early 50s, especially in countries where potable water is scarce as in the Arab Gulf, Caribbean and some areas of North America [15,16].

The composition of the brackish water varies according to the source, although the concentration of salts varies from place to place, the ratio between the most abundant constituents is practically constant.

The configuration used in the Unit 02 reactor plant is the pressure-sprinkler type with an arrangement in which the brackish water introduced into the chamber through a spray system, which sprays it onto a plasma hydrogen vortex and vaporizes it. The salts are then deposited in the bottom of the vessel in the form of a salt of gem. The superheated steam sent to Unit 03 in order to generate energy (see Figure 4).

Figure 4: Desalination Thermal Reactor – Unit 02A / B.

Source: Sena (2016)

Power generation system

The Stirling engine surprises for its simplicity, since it consists of two chambers in different temperatures that heat and cool a gas of alternating form, causing expansions and cyclical contractions, which makes move two pistons connected to a common axis. In order to reduce thermal losses, a regenerator usually installed between the hot and cold chambers where the heat (which would be rejected in the cold chamber) is stored for the next heating phase, greatly increasing the thermodynamic efficiency.

Because, they are very simple machines with easy maintenance and operation, low noise and vibration, these peculiarities made possible their use in a distributed way throughout the entire production chain, reducing the cost of energy and the need for large generation units. The use of the Stirling engine for the production of electricity was the best way to reduce costs and increase energy production. Thus, the option of using the Stirling engine as drives for power generation units is due to its low cost of manufacturing, the ease of working with small generating units and the distribution of several generating units along the production unit (see Figure 5). Thus, Stirling engines used along the production line, using the steam generated in the Unit. 2A and Unit. 2B, and heat of the yolk salt, which the lower nozzle of these units' extracts.

Figure 5: Stirling Engine Model.
Source: Sena (2016)

The design of the Stirling engines obeyed an ALFA type architecture, with 2 pistons, in a 'V' structure (see Figure 05), guaranteeing 1800 rpm on the steering wheel that drives the mechanically coupled generator. To meet this architecture, five 25 cc chainsaw motors acquired from the recycling company and dismantled.

DEMETER Project

Hydroponics is an alternative technique of protected cultivation, in which the soil replaced by an aqueous solution containing only the mineral elements indispensable to the plants. This is a widespread technique throughout the world and its use is growing in many countries. Its importance is not only because it is a technique for horticultural research and vegetable production it is also being used as a tool to solve a wide range of problems, such as reduction of soil and groundwater contamination and manipulation of nutrient levels in culture.

The success of hydroponic cultivation directly related to the nutrient solution, since it determines the growth of the plants and the quality of the final product. Thus, the disadvantages of hydroponics projects lie in two primary elements, the energy consumption and the quality of the water supplied. It is in this context that the DEMETER project arises, which created a simple systematics of the cultivation bases based on recycled plastic structures to support coconut fiber trays to fix the plants to reduce the productive costs [7,15,21].

The DEMETER project uses a systematic rationalization in the use of water and energy, basing its process on a continuous control of what generated, and what consumed. Thus, it developed to produce fruits, vegetables and vegetables, at a low cost, in a hydroponic process system, reducing water consumption, providing a larger quantity of food, producing biogas to feed the CHIRON project and treating its effluents to reduce impact on the environment. With this, the process will allow the generation of energy, production of vegetables, vegetables and / or fruits, and biogas, in addition to recovering pure water and fertilizers not absorbed by plants.

Unit A – Hydroponics Bench

A well-structured production is synonymous with good yield, low cost and quality of the final product. Thus, in view of the various techniques available for hydroponic cultivation, the GAIA project chose to use a passive sub-irrigation system in order to reduce costs and reduce production (See Figure 6).

The project of the shed was made from recycled plywood with recycled aluminum arch cover, with the following dimensions: 8.0 m wide, 21.0 m long; 4.5m high on the sides and 5.5m, in the central span. On the side and front walls were made openings with plastic screens. This structure built on a floor made with stones

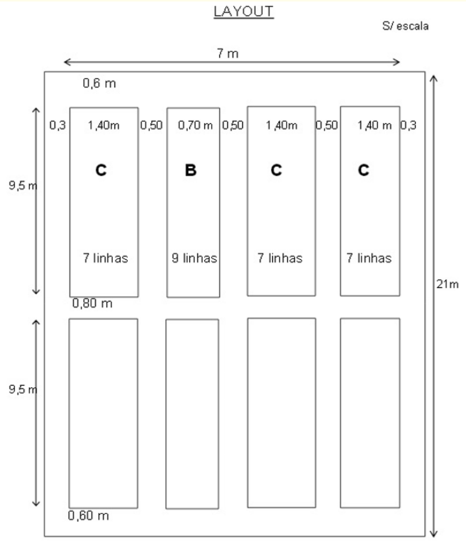

Figure 6: Bench Layout.
Source: Sena (2016)

and cement. The cover consists of transparent polycarbonate sheets, 4mm thick, treated against UV rays, all materials used came from construction or demolition discards.

A PVC pipe leads the nutrient solution pumped from the reservoir to the top of the bench, from where the solution injected into the hydroponic profile. The injected solution traverses the sloping profile, with gravity being the only driving force. The level difference between the electric pump and the injector system is 0.80m.

The benches mounted two by two on recycled wood beams, with the profiles spaced apart and between the pairs of plots; a corridor left to facilitate transit and operability (see Figure 6). The width of the corridor and the spacing between the profiles also designed to avoid competition between plants belonging to different treatments. The nutrient solution reservoirs supported in boards at the same height, in order to avoid the influence of the unevenness of the terrain on the flow of electro pumps.

The injector system was composed of an emitter that leaves the pipe and extends through a flexible hose to the hydroponic profile, with an average flow of 1.3 l/minute. The surplus not injected into the profile returns to the reservoir through PVC tubing, at the end of which a 90º knee connected in order to favor the aeration of the nutrient solution.

They also set up individualized automatic filling systems for each plot and built with continuous section PVC pipes with a diameter of 150 mm. This type of system allows the automatic exit of water to a nutrient solution reservoir by means of a faucet, allowing the maintenance of the volume contained in it. The supply tank was fitted with a graduated ruler attached to a transparent hose, which allowed the calculation of the evapotranspiration volume per plant in a given period. The Bench top Structure based on a 5-layer process, as described in figures 7 and 8.

Figure 7: Hydroponic table sketch.
Source: Sena (2016)

Figure 8: Internal structure.
Source: Sena (2016)

The waterproofing layer has the function of protecting and avoiding infiltrations and losses of water and nutrients in association with the drainage layer serves to capture the water with nutrients giving discharge to the excess water. The supporting drainage layer was composed of crushed stone; pebbles have thickness of 7 to 15 mm. The fixing substrate is made of coconut fiber, in brick format, treated and sanitized, making the substrate lighter and suitable for root development.

Unit 02B – Thermal Treatment Reactor

The composition of the water mixed with the fertilizer would be a very dangerous contaminant for the environment, although the concentration varies according to the source, the productive stage and the type of planting and the relation between the most abundant constituents is practically constant. Among these constituents are chlorides, sulfates, iodides among others.

The configuration used in the Unit 02B reactor plant is similar to that of Unit 02A, having a sprinkler under pressure with an arrangement in which water with nutrients is introduced into the chamber through a spray system, which sprays it on a plasma hydrogen vortex vaporizing it. With this, the nutrients in the form of solid fertilizers deposited at the bottom of the container. The superheated steam sent to Unit 03 in order to generate energy (see Figure 4).

Unit B – Biodigester

In order to make the system self-sufficient, the DEMETER project is equipped with a simple biodigesters for methane generation, which feeds the Reactor Unit 01. Thus, the biodigesters constructed from 250-liter plastic drums used, to collect the gas produced and to drain the fluids; each unit was interconnected by PVC pipe [4-6].

The raw material for the process was greenhouse waste of production and material organic of restaurants, which had no commercial value, being careful not to add meat foods, animal fats and blood. The residues collected initially in the kitchens of residences and nearby restaurants. The choice of this raw material related to the ease of obtaining the products for fermentation. However, for the biodigestor to take place satisfactorily there was the addition of swine manure.

The biogas produced in unit 03, complemented the methane consumption for the Unit 01 reactor, at a ratio of 58% of the needs. When the biodigesters would been in full operation, they could fully replace the system consumption (see Figure 9).

Figure 9: Biodigestor structure.
Source: Sena (2016)

The results analysis

The production of energy, water and food in sufficient quantity and at competitive prices is important for economic development. Currently, there is great concern about the environmental aspects of production in these segments, with emphasis on the use of renewable sources, which do not degrade the environment and guarantee the productive continuity for future generations.

Over the years, there is a growing belief that infrastructure in the world should be composed of a mix of agricultural, livestock, water and energy sources of different shapes, characteristics and sizes, in order to increase food security and availability, drinking water, energy to ensure global development.

Thus, when an investment considered a disbursement made to generate a flow of future benefits. In order to evaluate the investments, there are indicators of analysis capable of assisting in the perception of the behavior between risk and return, the Project GAIA would have a difficulty of embedded in this or that segment, to make feasible this analysis.

Thus, the GAIA project designed to improve the social and economic conditions of the Brazilian semi-arid region. The project built near the city of Quixabeira, north-central Bahia, Brazil, and operated for 14 months, with the support of local farmers, who helped in the project to produce energy, treat brackish water and produce foods.

Techniques resulting

The GAIA Project utilized its two reactors and five Stirling-powered generators to treat brackish water from artesian wells, generate energy and produce food. To perform this procedure, the CHIRON Project miniaturized to work with limited flow rates to meet the needs of the DEMETER project. Thus, the project conceived as a pilot plant with the following technical characteristics:

- Total flow rate: 50 l/h;
- CH_4 flow rate: 300 l/h;
- Average Salts Concentration: 27.3 g/l;
- Generator efficiency: 0.891
- Maximum efficiency of the CH_4 reforming reactor for H_2 generation: 90%
- Water vapor temperature conditions: 589ºC a 25.6 Bar;
- Water consumption of the CHIRON system: 14 l/h.

It found that the GAIA project consumes 6.14 KW of energy to meet the energy demands of the CHIRON and DEMETER projects. In order to cope with the energy needs of the system, 5 Alpha-type Stirling motors were built, each of which drives a 3.2 KVA generator, totaling 16 KVA of energy, which can be driven individually as power requirements they are performing. The GAIA project consumed 38.4% of the energy produced, and 61.6% was made available to the grid for other uses and to remunerate the project.

The Demeter project started operating 1 month after the departure of the QUÍRON project and closed the activities about 1 month before the end of the activities of the GAIA project, this procedure adopted in order to accumulate inputs that meet the conditions of hydroponics.

After the start of the Demeter project, UNIT A had the following productive behavior during the 12 months continues (see Figure 10-12) and 5 harvests were taken, that is, 1 every 60 days per bench

Figure 10: Parsley (*Petroselinum crispum*).

Figure 11: Coriander (*Coriandrum sativum*).

Figure 12: Chive (*Allium schoenoprasum*).

After 5 harvests, in 12 months, it was observed the productive yield of the two hydroponic benches reached 96.7%, with a uniform growth of the plants and a significant reduction in the action of pests and contaminants, with a production of more than 84 packs per harvest.

The big problem in hydroponics stands is water quality, so the DEMETER project benefits from using pure water produced by the CHIRON project and is sent to the feed tanks of each stand to be prepared with nutrient solutions indicated for each plant. This process allowed the feeding of plants to be uniform and without contaminants, ensuring a recirculation of the water avoiding its contamination.

The reuse water from the benches was treated in a second desalination unit, Unid-3, smaller than the main one, which purifies the water and recovers part of the dissolved fertilizers. At the same time as the water is treated thermally, at a temperature of 589°C, any organic residue that is contained in the water will be literally incinerated, thus ensuring the perfect sanitation of the water.

Economic Resulting

When analyzing the feasibility of projects for water supply, energy generation and food production, one should not only consider the question of return on investment, but also the impact on the entire productive and social context, especially for localities lacking these resources. Therefore, of utmost importance is not to dwell on a simplistic reading of numbers and results, but rather on the complexity of the socioeconomic recovery of poor and socially at risk groups. Thus, in areas where the majority of the population does not enjoy access to potable water, energy and/or food, a system project that brings together energy generation, food production and water provides the beneficiaries with the minimum conditions and quality of life, thereby contributing to the improvement of the HDI of the population [12,15,20].

The GAIA project was a pre-determined research funded by a public research investment fund with a limited value of us$ 10,000.00 to prove that it was technically and economically feasible. With the architecture of the project working with the thermal cycle of the H_2, it was verified the non-existence of the generation of residues, nor emanations of gases of the greenhouse effect, in the operation of the system, until the residues of the harvest were used for the biodigesters. Thus, the union of the processes added to a system of financial control, allowed the recovery of the investment in 6 months.

Throughout the operating time of the GAIA project, it was possible to raise the productive costs and to observe that, based on the standards of taxes and costs of inputs in Brazil, the project has a low maintenance cost, although it is all developed with pieces of scrap and an average cost of labor. In this way, the average cost of the plant is low per hour of operation. The cost of each product, including taxes and operating cost, can thus be demonstrate:

- **Pure Water**: Us$ 0.06/l/h;
- **Electricity:** Us$ 0.10/KWh;
- **Carbon:** Us$ 0.86/Kg/h;
- **Hydrogen:** Us$ 0.86/Kg/h;
- **Chive:** Us$ 0.14/Kg;
- **Parsley:** Us$ 0.15/Kg;
- **Coriander:** Us$ 0.12/Kg;
- **Manure:** Us$ 0.031/Kg; e,
- **Salt:** Us$ 0.18/Kg/h.

With the diversity of byproducts generated, the GAIA project had a multiplicity of revenues that allowed investments to be recovered within a period of 6 months and a profit on the investment of 78.8%, despite being a basic small plant, built from scraps. Therefore, during the 12 months of operation, the GAIA project had the following financial results (Table 1)

Descriptive	Value in Us$	
	Monthly	Total
Investment	2,500.00	10,000.00
Operational Cost	956.00	13,384.00
Gross Profit	2,560.00	30,720.00
Taxes and Fees	1,070.00	12,840.00
Net Profit	1,490.00	17,880.00
% Return	78,8%	

Table 1: GAIA project financial results.

Source: Author

These results reflect the reality of the Brazilian market, incidental taxes and charges, labor costs and employed automation. These values will change according to the economic, fiscal and equipment conditions present in each country.

Conclusions

The GAIA project combined two different guideline projects and strands, see Figure 2, combining a plasma reactor for H_2 generation, a steam desalination unit and a turbo-generator of electric power with a hydroponic bench for vegetable production and fruits, in a very organic.

The GAIA project, when it unified the two projects, created a very high sustainable and closed process, ensuring that the most critical points in DEMETER, namely water quality and purity, waste treatment and continuity of energy supply, were fully served by CHIRON.

However, as from 2014, Brazilian public accounts began to feel the effects of the unbridled corruption practiced by politicians and the lack of control of public spending. Thus, the Brazilian government systematically cut funding for research. In 2016, all funds from the GAIA project were finally cut, which made it use its own resources, which kept it for another 12 months. At the end of this period, the NDTA forced, by governmental decision, to deactivate and dismantle the entire GAIA project, since the researchers had cut all their salary. Even in its short duration, a new form of socio-economic approach to food production was found, promoting an improvement in social conditions and human development. With this new solution, semi-arid areas become productive areas, no longer influenced by salinity, expansion of cultivated areas, availability of energy, food, pure water and economic gains.

It is worth noting that the project's application potential is directly associated with its uniqueness, simplicity, portability, modularity and constructive speed. Therefore, the GAIA project is fully applicable for the treatment of brackish water with the objective of producing food in hydroponic benches, since it works as an alternative to exploit the potential of coastal waters without the need for major engineering projects and civil works for its implementation. In addition, the generation of energy is justified by the thermal availability of the process, as opposed to the conventional production of separate thermal and electromechanical energy, which, from this point of view, has led to the search for the most appropriate technology for the utilities. To provide the highest possible energy efficiency, so the option to use Stirling engines to power the generators, due to its low production cost and ease of maintenance.

However, the investment strategy should include other factors. The first one related to the economic efficiency or the economic return of the enterprise, even more important than the energy efficiency and the productive capacity of food, refers to the cash flow in order to generate the greatest possible economic benefit.

In the process, it was possible to determine that the most relevant costs in the project come from four basic factors: energy, pure water, natural gas and seeds (inputs), which have a much greater influence than other costs (equipment, installations, maintenance etc.). In this way, the GAIA project prioritized minimizing costs in 3 of the 4 items, which were energy, gas and water, directly impacting the final cost of the project.

As for the question of the cost of natural gas for the plasma reactor, it is mainly due to the increase in the price of natural gas in Brazil. To reduce this cost a biodigesters system has introduced for the production of biogas, which can supply the CH_4 gas needs for the process, greatly reducing the operational cost, besides benefiting the environment, avoiding the release of gases of the greenhouse effect into the atmosphere. In the project, this saving was of the order of 46%, replacing the natural gas by the biogas. The replacement was not complete, since the GAIA project only operated for 14 months, which was not sufficient for biomass production and its fermentation in biodigesters. Therefore, there was no time to mature all biomass, available for the fermentation process and biogas production, thus reducing the amount produced.

It should note that the GAIA project does not emit greenhouse gases and in addition promotes the sequestration of the carbon, because there is no emission of CO_2 and CH_4. The carbon that produced by pyrolysis of cold plasma is stored in the bottom of the reactor for nobler uses, such as carbon fiber, carbon nanotubes, among others.

During two harvests, tests carried out, using colloidal carbon. These had been administered the roots of the plants in order to verify their impact as a plant fertilizer and its influence on plant growth and quality. The C incorporated into only one of the rows of bank 1, in different concentrations to verify this influence. Thus, as can see in figure 13, when adding colloidal carbon at various concentrations in coriander (*Coriandrum sativum*) roots, plant growth affected and, depending on the concentration, the results were quite interesting.

Figure 13: Coriander (Coriandrum sativum) - with carbon concentration varying from 1% to 15%.
Source: Author

It was possible to observe that, when adding the colloidal carbon to the roots of the plants, they had a moment of development, gaining mass, quickly, having its growth directly influenced by the concentration of carbon added in the water, as can observed in the figure. 13. It was also observed that its nutritional value was not affected nor its flavor, it was verified only that the acidity was reduced, when the addition of more than 6% of C.

Thus, the GAIA project presented, which represented a gigantic effort for the research group, since the NDTA had its financial resources cut, the professors and researchers dismissed without salaries and scholarships.

Nomenclatures

ANA	National Water Agency	**HDI**	Human Development Index
NFT	Laminar Flow of Nutrients	**MCT**	Science and Technology Ministry
O_2	Oxygen	**CH_4**	Methane
C	Carbon	**H_2**	Hydrogen
CO	Carbon Monoxide	**CO_2**	Carbon Dioxide

Table 2

Bibliography

1. ANA – Agência Nacional de Águas (National Water Agency – Brazil). Relatório de Conjuntura dos Recursos Hídricos (Report of the Conjuncture of Water Resources.). Brasilia: ANA (2017).
2. Plano Nacional de Recursos Hídricos Quinquênio 2015-2020 (National Water Resources Plan - Quinquennium 2015-2020). Brasilia: ANA (2015).
3. COOK and Hadrian F. "The Protection and Conservation of Water Resources". 2nd Edition. New Jersey: Wiley-Blackwell (2017).
4. Fulford David. "Small-scale Rural Biogas Programmes: A handbook". 1st edition London: Practical Action Publishing, (2015).
5. Hill Brad. "Biogas: Technology and Principles". 1st ed. New York: NY Research Press, (2015).
6. HosseinI Seyed., *et al*. "Development of biogas combustion in combined heat and power generation". *Renewable and Sustainable Energy Reviews* 40 (2014): 868-875.
7. Jacobson Andy. "Hydroponics: The Essential Hydroponics Guide: A Step-By-Step Hydroponic Gardening Guide to Grow Fruit, Vegetables, and Herbs at Home". New Jersey: CreateSpace Independent Publishing Platform (2016).
8. Letcher Jonathan. "Farm Digesters: Anaerobic digesters produce clean renewable biogas, and reduce greenhouse emissions, water pollution and dependence on artificial fertilizers". Cambridge: Green Books, (2015).
9. Loucks Daniel P and BEEK, Eelco van. "Water Resource Systems Planning and Management: An Introduction to Methods, Models, and Applications". 1st edition New York: Springer (2017).
10. Mcnabb David E. "Water Resource Management: Sustainability in an Era of Climate Change. 1st ed. Basingstoke: Palgrave Macmillan (2017).

11. MCT - Ministério de Ciência e Tecnologia (Ministry of Science and Technology). Comissão interministerial de mudança global do clima. Status atual das atividades de projeto no **âmbito** do mecanismo de desenvolvimento limpo (MDL) no Brasil e no mundo – Relatório Anual (Interministerial Commission on Global Climate Change. Current Status of Clean Development Mechanism (CDM) Project Activities in Brazil and the World - Annual Report). Brasília: MCT (2017).

12. Rackley Stephen A. "Carbon Capture and Storage". 2nd Edition. Oxford: Butterworth-Heinemann (2017).

13. Ray Patrick A and Brown Casey M. "Confronting Climate Uncertainty in Water Resources Planning and Project Design: The Decision Tree Framework". 1st edition London: World Bank Publications (2015).

14. SENA André P., *et al*. "Nereu Project: Construction of a Plasma Reactor for Reform of Methane for Treatment of Wastewater of The Marine Farms. In: Taner Yonar, editor. Desalination. London: INTECH, (2017)

15. "Neptune Project: A Reactor of Cold Plasma to Treat Seawater for Use in the Food Production. In: Jenessa Terrell, editor. Water Filtration System". 1st edition New York: Nova Publishers (2016): 27-70.

16. "Chiron project: Reform of methane from a cold plasma reactor with hydrogen production for desalination and energy cogeneration". *Energy Conversion and Management* 86 (2014) 933-943.

17. Spellman Frank R. "The Science of Renewable Energy". 2nd Edition. New York: CRC Press (2016).

18. Toensmeier Eric and Herren Hans. "The Carbon Farming Solution: A Global Toolkit of Perennial Crops and Regenerative Agriculture Practices for Climate Change Mitigation and Food Security". Chelsea: Chelsea Green Publishing (2016).

19. United States Congress Senate Committee. Carbon Sequestration: Measurements and Benefits - Scholar's Choice Edition. Washington D.C.: Scholar's Choice, (2015).

20. Ussiri David A., *et al*. "Carbon Sequestration for Climate Change Mitigation and Adaptation". 1st ed. New York: Springer (2017).

21. Walsworth William. "Hydroponics: Everything You Need to Know to Start an Expert DIY Hydroponic System from Home. New Jersey: CreateSpace Independent Publishing Platform (2016).

22. Wang Ting and Stiegel Gary J. "Integrated Gasification Combined Cycle (IGCC) Technologies". 1st edition. Sawston: Woodhead Publishing (2016).

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