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The Energy Sources that Have Changed the World Throughout History and the Required Future Sustainable Energy System

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ABSTRACT
This article aims to present the energy sources that have changed the world throughout history and the sustainable energy system required for the future.

Keywords: Energy sources, Energy sources in prehistory, Coal, Oil, Natural gas, Electricity, Biomass energy, Wind energy, Hydrogen, Nuclear energy, Solar energy, Ethanol, Biodiesel, Sustainable energy system of the future

INTRODUCTION

This article aims to present the energy sources that have changed the world throughout history and acted as a factor of progress for humanity, as well as the sustainable energy system required for the future. In scientific terms, energy is the capacity of a physical system to perform work, that is, to produce movement, change or transformation. It is a physical quantity that can be expressed in various ways and that cannot be created or destroyed, only transformed. Energy is an essential input for human beings that has constituted itself throughout history as a factor of economic and social development, that is, of human progress. It can be said that the most basic need of human beings is the search for energy to keep their bodies and their production and transportation systems functioning. This aspect, the fulfillment of physiological needs, predominated in the history of humanity until human beings discovered that they could control forms of energy that would be useful to them, such as fire, which represented a very important milestone for humanity, with the use of thermal energy, being able to cook their food and keep warm. In the early history of humanity, the domestication of animals provided the mechanical energy needed for transportation and agricultural production. A few millennia ago, firewood, hydraulic energy from rivers and wind energy (aeolian) also began to be used based on available technology. However, it was only with the advent of the Industrial Revolution, about three centuries ago, that energy assumed the status of a fundamental factor in the progress of humanity. From prehistoric times to the contemporary era, humanity has used and continues to use various sources of energy such as fire, firewood, hydroelectricity, coal, oil, natural gas, wind energy, hydrogen, nuclear energy, solar energy, biomass energy, ethanol and biodiesel, among other sources of energy.

ENERGY SOURCES IN PREHISTORY

For a long time, in the early days of humanity, muscular strength was the main source of energy used by man. In the early history of humanity, the domestication of animals provided the mechanical energy necessary for transportation and agricultural production. The discovery by human beings that they could control forms of energy that would be useful to them, such as fire, represented a very important milestone for humanity, since, with the use of thermal energy, they were able to cook their food and keep warm. The use of fire began around 7 thousand years B.C., in the Neolithic period. A few millennia ago, the hydraulic energy of rivers and wind energy were used by humanity based on the technology available. Around 12,000 years ago, the Agricultural Revolution marked the beginning of the use of animal traction, wind power and waterfalls in agricultural and livestock production (Alcoforado, 2021).

During Antiquity, the use of wind in sailing was essential for colonization and trade along the shores of the Mediterranean Sea, replacing rowing navigation that used human muscle power. During the Roman Empire, from 31 BC to 410 AD, firewood was widely used to produce weapons in the metal forging process. This caused the deforestation of much of Italy and the Iberian Peninsula. At the same time, very far away, more specifically in China, major innovations in hydraulic technology were introduced, with the creation of water lifting devices and irrigation systems. From the mastery of fire until the advent of the 1st Industrial Revolution in the 18th century, there was no major evolution in the way humanity used energy. Changes in the global energy matrix, in terms of the diversity of sources and usage patterns, did not change much over the centuries until the 1st Industrial Revolution (Alcoforado, 2021).

THE USE OF COAL FROM THE 18TH CENTURY ONWARDS IN ENERGY PRODUCTION

It was only with the advent of the 1st Industrial Revolution, also known as the "age of coal and iron", which took place in England in 1786, that the use and production of energy assumed fundamental importance in the replacement of men and animals by machines. With the 1st Industrial Revolution and the consequent industrialization process, the need for energy increased and new primary sources, with greater energy density, were introduced. The use of coal as an energy source marked the end of the era of renewable energy represented by the use of wood and the limited use of hydraulic and wind energy used since the dawn of humanity, to begin the non-renewable era of energy, the era of fossil fuels with the use of coal and the invention of steam engines (Alcoforado, 2021; Smil, 2018).

A steam engine has a boiler that, with the heat from burning fuel, turns water into steam, with the purpose of transforming the hot energy that is released by burning fuel, coal. The adoption of the steam engine was slow, taking a century after James Watt's patent (1769) to be used to transform industrial production and land transportation with the advent of the railroad and its use in long-distance shipping with steam ships. The replacement of charcoal with coke in iron smelting was one of the greatest technical innovations of the modern era, as it ended the unsustainable use of wood in England and dramatically increased iron production. Furthermore, coal established the basis for the modern steel industry and paved the way for the advent of the key metal of industrialization, iron (Alcoforado, 2021; Smil, 2018).

THE USE OF PETROLEUM AND ITS DERIVATIVES (GASOLINE, DIESEL OIL, FUEL OIL AND KEROSENE) FROM THE 19TH CENTURY ONWARDS IN ENERGY PRODUCTION

From 1860 onwards, new transformations emerged in the industry in England. This phase was called the 2nd Industrial Revolution, which became known as the "age of steel and electricity". With the 2nd Industrial Revolution, which lasted until the first half of the 20th century, new fuels with greater energy power were needed, and petroleum was the fuel that combined these properties. Thus began a new phase in the use of liquid fuels that continues to this day. Initially, oil was only used to produce kerosene and lubricating oils. At that time, the gasoline generated during the distillation of oil was thrown into rivers or burned. Sometimes it was mixed with kerosene to produce a dangerous explosive. Among the inventions that emerged during the 2nd Industrial Revolution were the Bessemer process for transforming iron into steel, which allowed for the production of steel on a large scale, the dynamo, which allowed steam to be replaced by electricity, and the internal combustion engine, which allowed the use of oil on a large scale, creating conditions for the use of its derivatives in automobiles and, later, in trucks and airplanes (Alcoforado, 2021; Smil, 2018).

The use of gasoline as a fuel for motor vehicles only began after the invention of internal combustion engines and the large-scale production of automobiles. The automobile became viable with the invention of the internal combustion engine and the discovery that it was possible to use a petroleum derivative, gasoline, as fuel, which occurred in 1876. Nikolaus August Otto, a German engineer and inventor, was the one who invented and built the first four-stroke internal combustion engine and determined the theoretical cycle under which the internal combustion engine works, the well-known Otto cycle. From then on, the demand for petroleum derivatives, especially gasoline, increased dramatically in industrialized countries. Petroleum, which until then had only been used to obtain kerosene, became a source of gasoline. A few decades later, this same trend transformed diesel into a fuel used in jeeps and trucks, and fuel oil into a widely used fuel in industry from World War II onwards (Alcoforado, 2021; Smil, 2018).

THE USE OF NATURAL GAS FROM THE 19TH CENTURY ONWARDS IN ENERGY PRODUCTION

Natural gas has been known to humanity since ancient times. In places where mineral gas was naturally expelled to the surface, ancient peoples such as the Persians, Babylonians and Greeks built temples where they kept the "eternal fire" burning. The discovery of natural gas dates back to between 6000 and 2000 BC in Iran. On the European continent, natural gas was discovered in 1659. The first exploration of natural gas, for commercial use, occurred in the United States in 1821, for public lighting and heating homes. There are historical records of the economic or socially beneficial use of natural gas in China in the 18th and 19th centuries. The Chinese used places where natural gas escaped to build blast furnaces for the production of ceramics and metallurgy in a still rudimentary form. Natural gas is a fossil fuel composed of a mixture of hydrocarbons such as methane, ethane and propane. It is found in underground deposits commonly associated with oil, but it can also occur in isolation. In addition to the production of electricity, especially in thermoelectric plants, natural gas is also used to produce heat in various applications, such as residential and industrial heating, as a raw material for industry, as a fuel for vehicles (NGV) and in cogeneration processes (using waste heat to produce electricity, among other purposes) (Gás natural, 2025).

In the 19th century, natural gas was normally obtained as a byproduct of oil production. At that time, natural gas was not widely used, and all of its unwanted production became a major disposal problem for oil refineries. Natural gas began to be used on a larger scale in Europe at the end of the 19th century, with the invention of the Bunsen burner in 1885, which mixed air with natural gas, and with the construction of a leak-proof gas pipeline in 1890. However, gas pipeline construction techniques were incipient, and there was no transport of large volumes over long distances; consequently, natural gas's share in the market was small compared to oil and coal. Between 1927 and 1931, there were already more than 10 large gas pipelines in the United States, but they did not reach interstate. By the end of 1930, advances in technology had made it possible to transport natural gas over long distances. Thousands of kilometers of gas pipelines were built after 1960, given advances in metallurgy, welding techniques, and pipe construction. Since then, natural gas has been used on a large scale by several countries, including the United States, Canada, Japan, and the vast majority of European countries. This is mainly due to the numerous economic and environmental advantages that natural gas offers (Gás natural, 2025).

THE USE OF ELECTRICITY FROM THE 19TH CENTURY ONWARDS IN ENERGY PRODUCTION

Advances in scientific and technological knowledge made it possible to use electricity and invent electrical machines in the 19th century, along with the introduction of motor vehicles, which laid the foundations for the introduction of the modern consumer society, characterized by an energy intensity never seen before in the history of humanity. It was in 1913 in the United States, with the automobile industry as its flagship, that the Second Industrial Revolution was consolidated. With the 2nd Industrial Revolution, electricity emerged as a combined effort of several engineers and scientists, beginning with Michael Faraday's discovery of electromagnetic induction. This culminated in the work of Thomas Edison, who not only designed the first electric light bulb, but also built an electricity generating plant and a direct current electrical system in 1880 to supply power to customers in lower Manhattan in New York City (Alcoforado, 2021; Smil, 2018).

Later, in the last two decades of the 19th century, the famous "war of the electric currents" occurred between the alternating current advocated by Nikola Tesla and George Westinghouse and the direct current advocated by Thomas Edison. The difference between direct electric current and alternating current is that, while in direct current the electrons move in a single direction, alternating current has electrons that constantly change their direction. If the electrons move in a single direction, this current is called direct. If the electrons constantly change direction, it is called alternating current. For the distribution of electricity, alternating electric current is significantly more practical than direct current, since it is much easier to change the electrical voltage in alternating current than in direct current (Alcoforado, 2021; Smil, 2018).

Based on work with rotating magnetic fields, Nikola Tesla developed a system for generating, transmitting and using electrical energy from alternating current. Tesla partnered with George Westinghouse to commercialize this system. The "war of the electric currents" ended in favor of alternating current because it has the advantage of being able to easily lower or increase its electrical voltage through transformers and the transmission of high power is more economical, as it offers less energy loss. The electrical systems implemented throughout the world began to be based on alternating current. Today, alternating current is the norm for electrical power systems that produce electricity using hydroelectric plants and conventional and nuclear thermoelectric plants, among others (Alcoforado, 2021; Smil, 2018).

THE USE OF BIOMASS FROM THE 19TH CENTURY ONWARDS IN ENERGY PRODUCTION

Biomass is a substantial renewable resource that can be used as fuel for the production of electricity and other energy products. The first use of biomass as an energy source occurred in the Paleolithic Era, between one and two million years ago, when fire was used for heat and light. Later, biomass continued to be used for cooking, heating and lighting, mainly with the use of wood. In the 18th century, during the Industrial Revolution, biomass gained greater prominence for generating mechanical energy in steam engines. Wood was, for a long period of time, the main source of energy. It was used for cooking, steelmaking and ceramics. Oils from various sources were used on a smaller scale. The great leap forward in biomass came with the use of firewood in the steel industry, during the Industrial Revolution. In the 19th century, biomass played a key role in the production of mechanical energy with applications in industry and transport (Biomassa, 2024). The oil crisis once again stimulated the use of biomass in the 1970s, when the price of a barrel of oil quadrupled (Lorenzetti, 2024).

The use of biomass in energy production involves the use of organic waste, agricultural waste, wood chips or vegetable oil, among others. Sugarcane bagasse, with its high energy value, has been used to produce electricity in Brazil. The interest in converting biomass into electricity comes not only from its great potential but also from its low cost. In addition, biomass is a clean energy source. Planting energy crops can be a profitable alternative for rural landowners, who can use them, in addition to traditional crops, to generate energy for their own consumption and provide an additional source of income for the agribusiness and furniture sectors. For medium and large-scale energy generation, it has been difficult for biomass to achieve equal competitiveness with fossil fuels in the absence of an environmental tax or a reduction in the supply of these. Biomass can be an important global mitigation option to reduce the rate of CO2 accumulation by sequestering carbon and by enabling the cessation of the use of fossil fuels. The use of biomass as an energy source contributes only a small amount of carbon to the atmosphere. Locally, plantations can reduce soil erosion, provide a means to restore degraded areas, and offset emissions and local impacts of fossil fuel generation. Almost all experiments with biomass for energy generation are based on the use of waste fuels (mainly wood residues and agricultural residues) (Alcoforado, 2015).

THE USE OF WIND ENERGY FROM THE 19TH CENTURY ONWARDS FOR THE PRODUCTION OF ELECTRICAL ENERGY

Wind energy generates electrical energy from the force of the wind. It is a renewable, clean and abundant source of energy. The use of wind energy has ancient roots, with its use in sailing boats and windmills. The generation of electricity from the wind, as we know it today, began in the late 19th century, with the development of wind turbines for energy production. The first wind turbine was the work of Charles F. Brush, who, at the end of the 19th century, built a turbine in Cleveland (United States) that powered the lights in his mansion and several others. Wind energy is generated by the blades of wind turbines pushed by the wind. The blades turn and the generator transforms the kinetic energy into electricity that supplies the electrical grid (Iberdola, n.d.).

Wind energy, which transforms the power of an inexhaustible resource such as wind into electricity, is a sustainable and valuable investment for the future. Harnessing the wind requires the installation of wind farms, whether on land or offshore, with dozens of wind turbines. Wind energy is produced thanks to the wind turbine rotor, which transforms kinetic energy into mechanical energy, and the generator, which transforms mechanical energy into electrical energy. The best possible use of wind turbines, which are usually between 80 and 120 meters high, depends on the strength of the wind. Therefore, wind farms, which group together a large number of wind turbines and make it possible to obtain this energy in large quantities, must be located in locations where the wind is predominant (Iberdola, n.d.).

Wind turbines must be oriented in the direction of the wind. All wind turbines in a wind farm must be connected to each other by underground cables that carry the electrical energy produced to a transformation substation. Currently, there are two types of wind energy depending on where the wind turbines are installed: onshore (on land) and offshore (at sea). Wind energy offers numerous benefits to society, by helping to minimize the impact of climate change by replacing fossil fuels. As it does not require any combustion process, it is an energy source with low levels of greenhouse gas (GHG) emissions, which are mainly responsible for global warming (Iberdola, n.d.).

Both the cost per kWh of wind power produced and its maintenance are quite low. In areas where the wind blows stronger, the benefit is even higher. Wind farms are installed after a rigorous study and planning process. In addition, unpopulated areas are sought to avoid negative effects on their inhabitants, such as the noise produced by wind turbines. The process of building a wind farm is complex because there are many characteristics that influence where and when to install it. Among these, those that are essential to analyze are the spatial, temporal and vertical variations of the wind over the years. These parameters are analyzed with anemometers and wind vanes and the production of the future installation is estimated to guarantee its potential efficiency. Modern supercomputing techniques optimize the designs of wind complexes to maximize the generation of electrical energy.

THE USE OF HYDROGEN FROM THE 19TH CENTURY ONWARDS IN ENERGY PRODUCTION

The use of hydrogen as energy first occurred in 1839, when the British physicist William Robert Grove discovered the energy potential of hydrogen. Later, in 1960, liquid hydrogen was used as a fuel for space energy. Hydrogen, a chemical element abundant in the Universe and on Earth, has been explored as an energy source since the beginning of the 19th century. Hydrogen can be used to generate energy through processes such as combustion or electrolysis. The large-scale use of hydrogen for energy only began to develop in the 20th century, especially with the advent of space technology. In 1960, liquid hydrogen was used for the first time as fuel for spacecraft, marking a crucial point in the development of hydrogen energy (Alcoforado, n.d.).

The International Energy Agency (IEA) assured in a report dated 2019 that hydrogen is an energy of the future. Hydrogen appears to be a real alternative because it does not emit CO2 when associated with a fuel cell. It is important to note that hydrogen is also a renewable energy source that was discovered several centuries ago. When we talk about alternatives to fossil fuels, hydrogen often comes up, as it is a chemical element that makes up approximately 75% of the Universe. The first experiments related to hydrogen were observed at the beginning of the 19th century, in particular with the electrolysis of water and later with the development of fuel cells. It is important to note that it is only very recently that this fuel has resurfaced. In fact, this energy source has come to be considered as an alternative to replacing fossil fuels (Alcoforado, n.d.).

The main routes already tested for hydrogen production are: 1) water electrolysis; 2) production from biomass and natural gas; 3) coal gasification; 4) photolysis of water with solar radiation; and, 5) catalytic. Water electrolysis is the most attractive solution from an environmental point of view because the waste product of this process is water. It is possible to produce electricity from a fuel cell or stack using hydrogen to power the electric motor of motor vehicles or in fixed installations to produce electricity with powers of the order of a few thousand kW. The overall energy efficiency of a pair of fuel cells or stacks can reach values of the order of 50% to 60%, that is, twice that of heat engines (Alcoforado, 2015).

Hydrogen is a vector that is not present in its pure state in nature. It is therefore necessary to mobilize energy to extract it, transport it, and transform it. It is certainly much less polluting than other alternatives. It is possible to produce hydrogen through electrolysis. In this case, two electrodes (a type of metal rod) connected to a power source are inserted into a container with water. The rods have different polarities, and the energy that passes through them separates the hydrogen that is in the water. This process requires a lot of energy, because its energy efficiency is around 80%. This means that, to generate 80 kilowatts/kilo, 100 kWh of electricity would be needed. In this type of production, it is possible that carbon emissions are zero. However, this depends on the source of the electricity used (Alcoforado, n.d.).

There are several ways to produce hydrogen. Today, most of the initial production of electricity or hydrogen (depending on the process chosen) is of fossil origin. Green hydrogen production should be based on renewable energy sources (hydro, solar, wind and biomass) rather than fossil fuels. This is why two “types” of hydrogen are distinguished: 1) green hydrogen, which is produced by electrolysis, with the initial production of electricity from renewable sources (hydro, solar, wind and biomass); and 2) grey hydrogen, which is produced by chemical processes involving fossil fuels. Green hydrogen is of greatest interest because it is the fuel that helps our societies decarbonize in the face of the climate emergency (Alcoforado, n.d.).

Although the best-known use of hydrogen is probably in motor vehicles, there are many other possible uses. Fuel cells can serve as fixed power generation units for buildings. In some cases, they can also provide heat. Fuel cells are seen as potential power sources for aircraft. It is possible, for example, to use them as an emergency generator system. In addition, they can serve as an auxiliary power unit for the aircraft as a whole. Hydrogen can provide energy for ship propulsion. In addition to its use in the transportation sector, there are numerous other applications for hydrogen, such as decarbonization of industry, electricity storage, road, sea and air transportation, among others (Alcoforado, n.d.).

THE USE OF NUCLEAR ENERGY FROM THE 20TH CENTURY ONWARDS IN THE PRODUCTION OF ELECTRICAL ENERGY

The operation of a nuclear power plant in the generation of electricity consists of using the nuclear reactor (the main part of the plant) to simply boil water whose steam is used by a thermodynamic cycle to move an alternator and produce electrical energy. Nuclear energy is obtained from the fission of the nucleus of the enriched uranium atom, releasing a large amount of energy. The transformation of nuclear energy into electrical energy has been carried out in a controlled manner in a nuclear reactor through the nuclear fission of uranium as the main civil application of nuclear energy. Electricity was generated for the first time by a nuclear reactor on September 3, 1948, by the X-10 Graphite Reactor in Oak Ridge, Tennessee, United States, lighting an electric light bulb. Today, the United States is the country with the largest number of nuclear power plants, totaling 104, representing 18% of the country's energy matrix. France is at the top of the countries with the greatest dependence on this type of energy, using 80% of nuclear energy in its energy matrix (Alcoforado, 2021; Smil, 2018).

The main advantage of nuclear energy is that it makes it possible to avoid using fossil fuels such as oil, natural gas and coal to produce electricity, which has even been advocated by some environmentalists because it does not generate greenhouse gases. These environmentalists advocate a radical shift towards nuclear energy as a way to combat global warming resulting from the emission of greenhouse gases by fossil fuels, especially coal and oil. Compared to hydroelectric generation, the use of nuclear energy has the advantage of not requiring the flooding of large areas to form reservoir lakes, thus avoiding the loss of areas of natural reserves or agricultural land, as well as the removal of entire communities from areas that are flooded. However, nuclear power plants have the disadvantage of having to deal with the final disposal of their waste (atomic waste) that has not been resolved to date and of not being able to prevent accidents such as those that occurred in Chernobyl in 1986 and in Fukushima in 2011, which, when they occurred, assumed catastrophic dimensions (Alcoforado, 2021; Smil, 2018).

THE USE OF SOLAR ENERGY FROM THE 20TH CENTURY ONWARDS IN THE PRODUCTION OF ELECTRICAL ENERGY

Solar energy began with the development of the first silicon solar cell by Bell Laboratories in 1954. The solar energy incident on the Earth's surface is approximately 10,000 times greater than humanity's current gross energy demand. In the search for direct use of solar energy, several technologies have been studied, with special emphasis on photovoltaic conversion, thermal conversion and bioclimatic architecture. Photovoltaic conversion consists of the direct conversion of light energy into electricity, through the photovoltaic effect. Thermal conversion involves the direct use of the Sun's thermal energy, either for immediate use (water heating, industrial processes, etc.) or for generating electricity through a thermodynamic process (steam generation, etc.). Bioclimatic architecture, which consists of using materials and construction and architectural solutions in buildings to reduce the consumption of electrical energy for lighting and thermal comfort (air conditioning or heating), can also be seen as a way of using solar energy (Alcoforado, 2015).

Photovoltaic solar energy is obtained through the direct conversion of light into electricity. This effect, called photovoltaic, was discovered by Edmond Becquerel in 1839 and is defined as the appearance of a potential difference at the ends of a structure made of a given material, produced by the absorption of light (photons). The photovoltaic cell is the fundamental unit of this conversion process. The photovoltaic module is the basic unit commercially available, providing mechanical and environmental protection to the cells and allowing them to be used exposed to the elements. The module is composed of encapsulated cells electrically connected in series and/or parallel, producing voltage and current levels appropriate for use. Photovoltaic modules can also be connected arbitrarily in series and parallel, in order to form photovoltaic panels capable of supplying the voltage and current (power) levels required for a given application. Photovoltaic modules are highly reliable and highly durable devices, with a useful life of over 20 years (Alcoforado, 2015).

Grid-connected photovoltaic systems provide a complementary source to the large-scale electrical system to which they are connected. They do not normally use energy storage, since all the energy generated is delivered directly to the grid. To inject energy into the grid, a special inverter is used to transform the direct current produced by the photovoltaic panels into alternating current. The energy generated is normally injected into the low-voltage grid (110/220V alternating current) and the user's energy meter/tariff is bidirectional, balancing the energy generated with that consumed by the user. Inverters for injecting energy into the grid must meet strict quality and safety requirements so that these are not affected. Technical and commercial regulations regarding electricity concessionaires must also provide for this type of system. Large-scale photovoltaic plants are capable of competing with conventional sources of electricity. Calculations show that if the area flooded by the reservoirs of some hydroelectric plants were covered with photovoltaic modules, a higher installed power would be obtained than that of the plant in question, so that this possibility could become viable in the long term if the problem of storing the energy generated by the photovoltaic modules is solved, in order to make it firm. This is still one of the great advantages of hydroelectric plants, since the stored water guarantees firm energy, that is, energy production independent of short-term environmental variations (Alcoforado, 2015).

There are several applications of isolated photovoltaic systems for generating electrical energy, including: 1) telecommunications repeater stations; 2) (UHF, VHF, TV); 3) nautical signaling (navigation buoys and lighthouses); 4) telemetry, environmental monitoring and surveillance systems (weather stations, etc.); 5) cathodic protection systems for metal structures (oil pipelines, transmission line towers, etc.); 6) autonomous public lighting poles; 7) road signs (signs, hazard signs, etc.) and road emergency telephones; 8) sailing vessels; 9) camping and trailers; 10) portable electronic products (watches, calculators, toys, electronic diaries, Ni-Cd battery chargers, etc.); 11) military applications (use in campaigns, etc.); and, 12) pumping water in remote locations, far from the electrical grid, among others (Alcoforado, 2015).

THE USE OF ETHANOL FROM THE 20TH CENTURY ONWARDS IN ENERGY PRODUCTION

Ethanol is a type of alcohol obtained from the fermentation of raw materials rich in sugars, such as sugar cane and others. It is considered a biofuel, being widely used because it is a renewable energy source and is less polluting compared to fossil fuels. As a biofuel, ethanol is used in internal combustion engines with spark ignition (Otto cycle), and is a more environmentally friendly alternative to gasoline and other fossil fuels. Coming from plant sources, ethanol is produced primarily by fermenting sugars. One of the major advantages of ethanol is that it releases less carbon dioxide into the atmosphere compared to gasoline. The earliest use of ethanol dates back to the early 20th century, with pioneering experiments in

1925, and the first plant to produce fuel ethanol was built in 1927 at the Serra Grande Alagoas Plant. Almost 110 billion liters were produced worldwide in 2019 (Novais, n.d.).

Industrially, ethanol is a widely used solvent, with a favorable price and being a precursor to several organic compounds. It is used in the production of paints, solvents, cleaning products, detergents, among others. Ethanol is used as a solvent in the chemical industry, in addition to being used in the production of alcoholic beverages. Ethanol is also used in the formulation of vaccines, antibiotics and antiseptics. In the food industry, in addition to alcoholic beverages, ethanol is also present in vinegar, a product that has also grown in the cleaning field. Ethanol is produced mainly by the fermentation of sugars. The main use of ethanol is as a biofuel, obtained from plant matrices, such as sugar cane and corn. Its great advantage lies in the environmental aspect, since its plant matrix removes carbon dioxide from the atmosphere. Its main disadvantage is its dependence on climatic factors for good production. Ethanol began to be introduced into the Brazilian energy matrix at the beginning of the 20th century and in the United States in the 1970s of the 20th century (Novais, n.d.).

The main producers of ethanol in the world are the United States and Brazil. One of the main advantages of ethanol as a fuel is the CO2 offset it is capable of producing. The plant matrix from which ethanol is extracted, through photosynthesis, removes carbon dioxide from the environment during its production process. A study by Embrapa indicates that the production and consumption of ethanol from Brazilian sugarcane emits 73% less carbon dioxide when compared to the processes of obtaining and burning gasoline. The fact that it comes from a plant matrix also makes ethanol renewable, that is, its production is inexhaustible. From an energy standpoint, however, the calorific value of ethanol is lower than that of gasoline. Based on calorific value data, it is estimated that ethanol is only more viable than gasoline if the price per liter is less than 70% of the price per liter of gasoline in Brazil (Alcoforado, 2015).

THE USE OF BIODIESEL SINCE THE 20TH CENTURY IN ENERGY PRODUCTION

Biodiesel is an important source of renewable energy in energy production, especially as a substitute for diesel. Biodiesel was discovered in the mid-1890s by the inventor of the diesel engine, Rudolf Diesel. Worldwide interest in biodiesel grew in the 1970s, with the oil crisis and the emergence of climate change in the contemporary era. Biodiesel is produced from vegetable oils, animal fats and other waste through a chemical process called transesterification. The raw material for biodiesel is renewable, reducing dependence on fossil fuels. Biodiesel emits fewer greenhouse gases than traditional diesel, contributing to the reduction of air pollution. Biodiesel is considered a clean and sustainable source of energy. Biodiesel is used as a fuel in vehicle engines such as trucks, buses, tractors and cars, in addition to being used in industrial machinery engines, that is, it is a fuel for internal combustion engines with compression ignition or as a fuel for generating thermal energy, for example. It is known for replacing regular diesel in part or in whole. In addition to diesel and biodiesel, there is green diesel made from vegetable oils or animal fats. Green diesel is a hydrocarbon and undergoes a different process called hydro treatment, which makes it physically different from biodiesel, which is an ester (Raizen, n.d.).

It is important to note that regular diesel is of fossil origin and is obtained from petroleum and is non-renewable. Biodiesel, on the other hand, is an organic, clean, renewable and biodegradable fuel. In terms of environmental impact, the difference between the two fuels is significant: biodiesel is capable of emitting 98% less carbon dioxide than an equivalent amount of petroleum diesel. Biodiesel is obtained from renewable sources of plant origin (biomass), such as oilseeds (castor oil, palm oil, canola, sunflower, peanuts, soybeans and cotton) or animal fat, such as beef tallow and pork fat. Oils used in frying (cooking) are also an alternative raw material for the production of biodiesel. To obtain biodiesel, a chemical reaction with alcohol is necessary, in a process called transesterification. The transesterification process carried out in the biodiesel plant basically consists of the following steps: 1) The oil extracted from the plants is mixed with ethanol (from sugar cane) or methanol (which can be obtained from wood biomass) and then stimulated by a catalyst; 2) The catalyst, in turn, is a tool used for the oil and alcohol to react chemically; 3) The oil is separated from the glycerin (used in the manufacture of soaps) and filtered; 4) When reacting with the alcohol, the three fatty acid chains are detached from the glycerin and give rise to a biodiesel molecule (Raizen, n.d.).

SUSTAINABLE ENERGY SYSTEM REQUIRED FOR THE FUTURE

From the above, is demonstrated the importance of energy in its various forms as a factor in the progress of humanity, which has contributed to changing the world from prehistoric times to the present day. There is no doubt that human activities on Earth cause changes in the environment in which we live. Many of these environmental impacts result from the generation, handling and use of energy using fossil fuels. The main reason for the existence of these environmental impacts lies in the fact that, currently, global consumption of primary energy from non-renewable sources (oil, coal, natural gas and nuclear energy) accounts for approximately 88% of the total, with only 12% coming from renewable energy sources. This enormous dependence on non-renewable energy sources has led to, in addition to the ongoing concern about the possibility of these sources being depleted, the emission of large quantities of carbon dioxide (CO2) and other greenhouse gases into the atmosphere from fossil fuels (oil, coal and natural gas).

Everything suggests that, if the current trend in energy consumption is maintained, the share of fossil fuels (oil, coal and natural gas) in the global energy matrix will reach 80% by 2030. Oil, coal and natural gas are, in order, the most widely used energy sources in the final global energy consumption today. Oil has a dominant position among the energy sources used. Oil, coal and natural gas are, in order, the most widely used energy sources in the final global energy consumption. The industrialized countries of the OECD (Organization for Economic Cooperation and Development) are the largest consumers of energy, followed by China, Russia and other Asian countries. According to the International Energy Agency, oil and coal are the main culprits of CO2 emissions into the atmosphere, with the largest emitters being the industrialized countries of the OECD and China (G1.Globo, 2011).

The International Energy Agency (IEA) has warned that "the world is heading towards an unsustainable energy future" if governments do not adopt "urgent measures" to optimize available resources. Regardless of the various solutions that may be adopted to eliminate or mitigate the causes of the greenhouse effect, the most important action is, without a doubt, the adoption of measures that contribute to the elimination or reduction of the consumption of fossil fuels in energy production, as well as their more efficient use in transportation, industry, agriculture and cities (residences and commerce), given that the use and production of energy are responsible for 57% of the greenhouse gases emitted by human activity (G1.Globo, 2011). In this sense, the implementation of a sustainable energy system is essential.

In a sustainable energy system, the global energy matrix should only rely on clean and renewable energy sources (hydroelectric, solar, wind, hydrogen and biomass), and should therefore not rely on the use of fossil fuels (oil, coal and natural gas) and nuclear energy. Exceptionally, it could use natural gas because it is the least polluting fossil fuel and nuclear power plants because they are clean energy sources in the energy transition phase. Until the ideal condition is reached, the global energy matrix should go through an energy transition phase in which renewable and non-renewable energy sources would coexist. The technologies are already available to begin this historic energy transition, which will only occur with fundamental changes in energy policy in the vast majority of countries (Alcoforado, 2021).

Science and technology are already available to initiate this historic energy transition, which will only occur with fundamental changes in energy policy in the vast majority of countries. The transition from the current energy matrix based on fossil fuels to one based on clean and renewable energy requires, as a first step, the adoption of changes in energy policy worldwide, which consists of redirecting a large number of government policies in countries so that they are aimed at achieving the central objectives of energy efficiency and reducing the use of fossil fuels. For example: rewarding the purchase of efficient motor vehicles and electric vehicles with tax reductions, encouraging high-capacity mass transit alternatives on rails such as subways and light rail to replace automobiles, implementing railways to replace the use of trucks for long-distance freight transport, restructuring industries to make use of clean and renewable energy, and increasing taxes on fossil fuels.

The clean and renewable energy sources to be used preferably are hydroelectric, solar, wind, hydrogen, biomass (organic waste, sugarcane bagasse, agricultural waste, wood chips, vegetable oil, among others), ethanol and biodiesel. Exceptionally, nuclear energy may be used as a source of energy, which would be subject to restrictions due to the risks it poses, and natural gas, which is the least harmful fossil fuel to the environment. Clean and renewable energy sources are already a reality worldwide. The future of the energy sector worldwide will necessarily involve the use of clean and renewable energy sources. Clean and renewable energy is a concrete alternative to address environmental degradation and the misuse of the planet's natural resources. The use of clean and renewable energy is, without a shadow of a doubt, the rational way to guarantee the sustainability of planet Earth for current and future generations.

The use of solar energy and other renewable energies will bring about major changes throughout the planet, including the creation of entirely new industries, the development of new transportation systems, and the modification of agriculture and cities. The great challenge facing us today is to continue advancing science and technology in order to efficiently harness energy and economically utilize renewable resources. This is the alternative energy scenario that could replace the prevailing scenario of non-renewable energy sources, thus avoiding the global environment. This means that profound changes in global energy policy must be implemented to reduce the consumption of fossil fuels, which account for 80% of the world's energy supplies.

The direct conversion of solar energy into electricity and heat is likely to be the cornerstone of a sustainable global energy system. Solar energy is not only available in large quantities, but is also more widely distributed than any other energy source. Within a few decades, the Sun will be able to heat most of the water needed, and new buildings will be able to take advantage of natural heating and cooling to cut their energy use by more than 80%. Using electricity and burning fossil fuels directly to heat water will become rare in the coming decades (Alcoforado, 2015).

When we talk about alternatives to fossil fuels, hydrogen, a chemical element that makes up approximately 75% of the universe, often comes up. Hydrogen is an important source of energy for the future. A hydrogen molecule releases approximately three times more energy than its equivalent in gasoline. It is important to note that hydrogen is not an energy source, but rather an energy carrier. Hydrogen is a carrier that is not present in its pure state in nature. It is therefore necessary to use energy to extract it from water. From a molecular point of view, H20 is present throughout our planet. As a reminder, water is one atom of oxygen and two atoms of hydrogen (H_2O). It is important to note that H_2O represents almost 90% of the atoms (in number) present on our planet (Sirenergies, 2022).

The climate emergency favors the use of renewable energies (solar and wind). These means of energy production are questioned because they are intermittent. They only produce electricity when conditions allow. The use of hydrogen could, however, be a solution to deal with the intermittency of renewable energy use by using it in the process of producing and storing hydrogen. Although the best-known use of hydrogen is probably in motor vehicles, there are many other possible uses. Fuel cells can serve as stationary power generation units for buildings. In some cases, they can also provide heat. Fuel cells are seen as potential power sources for aircraft. It is possible, for example, to use them as an emergency generator system. In addition, they can serve as an auxiliary power unit for the aircraft as a whole. Hydrogen can provide the energy for the propulsion of the vessel. It is also possible for hydrogen to power service vehicles such as forklifts and trucks, as well as buses and trains (Sirenergies, 2022).

A sustainable energy system will only be possible if, in addition to abandoning fossil fuels, energy efficiency is also greatly improved. A sustainable energy system will only be possible if energy efficiency is greatly improved. Above all, the world would have to produce goods and services with one-third to one-half of the energy it currently uses. Technologies are already available that would quadruple the efficiency of most lighting systems and double that of new automobiles. Improvements in electrical efficiency could reduce energy needs by 40 to 75 percent. Heating and cooling needs of buildings could be cut to an even smaller fraction of current levels by improved heating and air conditioning equipment (Alcoforado, 2010).

REFERENCES

Alcoforado, F. (2010). *Aquecimento global e catástrofe planetária*. S. Cruz do Rio Pardo: Viena Gráfica e Editora.

Alcoforado, F. (2015). *Energia no mundo e no Brasil*. Curitiba: Editora CRV.

Alcoforado, F. (2021). Energy revolutions throughout history and its future evolution towards clean and renewable energy. *LinkedIn.* Available at https://www.linkedin.com/pulse/energy-revolutions-throughout-history-its-future-clean-alcoforado/

Alcoforado, F. (n.d.). Hydrogen as a solution to replace fossil fuel and avoid the emission of greenhouse gases. *Academia.edu.* Available at https://www.academia.edu/108878130/HYDROGEN_AS_A_SOLUTION_TO_REPLACE_FOSSIL_FUEL_AND_AVOID_THE_EMISSION_OF_GREENHOUSE_GASES

Biomassa. (2024, October 18). In *Wikipedia*. Available at https://pt.wikipedia.org/wiki/Biomassa

Gás natural. (2025, March 30). In *Wikipedia*. Available at https://pt.wikipedia.org/wiki/G%C3%A1s_natural

Iberdola. (n.d.). O que é a energia eólica, como ela se transforma em eletricidade e quais são suas vantagens? *Iberdola*. Available at https://www.iberdrola.com/sustentabilidade/energia-eolica

Lorenzetti, R. (2024, May 2). Histórico do uso da biomassa no Brasil e no mundo. *Blog Coontrol.* Available at https://blog.coontrol.com.br/uso-da-biomassa-no-brasil-e-no-mundo/

Mora, J. (2011). AIE: mundo se encaminha para futuro energético insustentável. *G1 Globo*. Available at http://g1.globo.com/mundo/noticia/2011/11/aie-diz-que-mundo-se-encaminha-para-futuro-energetico-insustentavel.html

Novais, S. A. (n.d.). Etanol. *Brasil Escola.* Available at https://brasilescola.uol.com.br/geografia/etanol.htm

Raizen. (n.d.). Biodiesel: Características do Biocombustível. *Raizen*. Available at https://www.raizen.com.br/blog/biodiesel

Sirenergies. (2022). L'hydrogène, énergie du futur? *Sirenergies*. Available at https://www.sirenergies.com/article/hydrogene-energie-du-futur/

Smil, V. (2018). *Energy and Civilization – A History*. Cambridge. Massachusetts: The MIT Press.

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