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A BRIEF HISTORY OF ENERGY

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ABSTRACT

The following paper has delved into the history of energy in terms of the earliest forms of energy and their role in society, and how these have changed overtime. Beginning from the earliest recorded uses of energy around 200,000 years ago, tracing the evolution of the usage of energy in human societies from the discovery of fire, domestication of animals, harnessing of heat, water flow, hydrocarbons and other newer primary energy sources. This paper has also discussed the scientific aspect behind them to explain how they were used and what purpose they served. Each form of energy involves its own explanation pertaining to physics and a certain individual with an idea. Ranging from well-renowned scientists to Greek inventors, people of a variety of backgrounds have made contributions to this progressive journey. Each forward step made in the changes that took place in the uses of energy often involved a problem or an inefficiency with the previous method, which have also been evaluated and discussed.

The uses and importance of energy have drastically changed overtime, and in a world like today's, society would collapse without it. The paper has also briefly discussed how the leap to thermal energy was the driving force for rapid advancements, and is also now the greatest threat to the planet from global warming; and made recommendations on possible policy actions.

Keywords: Energy, Work, Radiocarbon dating, Thermodynamics, Domestication

EARLY FORMS OF ENERGY

Energy, in simple terms, is the power obtained from the usage of physical and chemical resources. The word itself is derived from the Greek word energeia, coined by Aristotle, meaning 'work'. Similarly, in physics it is defined as the capacity for doing work. A commonly known fact is the first law of thermodynamics, the law of conservation of energy. This law states that energy can neither be created nor destroyed, only transferred from one form to another.

While humans mainly used their own energy to carry out mechanical tasks such as hunting,

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transportation, etc. the actual concept of the transferring of energy is one that has been in use by humans since as far back as 200,000 years ago (evidence has been found of 1.4 million years ago as well, however it is not as definitive), through the use of fire. The earliest certain evidence of this was found at Swartkrans, South Africa where burnt bones were found. However, the strongest evidence comes from Kalambo Falls in Zambia. Several things clearly suggesting the use of fire were found, such as charred wood, charcoal, etc. and through radiocarbon dating they were dated at about 61,000 BP (before present). This was used as a source of light, heat, as well as better nutrition due to cooked proteins. Other uses came years later, for example pit fired pottery, which was introduced in around 29,000 BC. More recently, about 8000 years ago, fire also became useful for the smelting of metals.

An important development to the history of energy sources was the domestication of animals. From around 4000 BC, the domestication of oxen began. While animals were domesticated from much before (goats, cattle, and pigs were domesticated from around 9000 BC, however these were mainly domesticated for a supply of food, leather, etc.), oxen were the first to be domesticated to carry out tasks that require energy. They were used to drag ploughs and wheeled wagons. The ploughs increased the output of crop of wheat and rice, while the wheeled wagons allowed humans to cover large distances. However, the main development to transportation came in 3000 BC, with the taming of horses. This allowed humans to travel great distances with considerable speed. Later came the domestication of camels, and further down the timeline, elephants.

Years later, in approximately 424 BC, a Greek playwright by the name Aeschylus wrote about the use of passive solar design, which refers to the heating and cooling of living spaces by use of the sun, when he wrote “Only primitives & barbarians lack knowledge of houses turned to face the Winter sun.”

As energy started playing a more important role in civilization, new methods of generation were slowly introduced. By around 300 BC, the Chinese began burning coal for heat, and carving it to use as trading commodities in village marketplaces. In fact, the burning of wood-derived charcoal in around 120 BC was so extensive, that over succeeding centuries, deforestation became a national environmental crisis in China. This use of coal allowed China to develop into a sophisticated economy and society.

Later, the use of windmills was first recorded between 500-900 AD. They were developed by the Persians, the first design being the vertical axis system, for uses such as wind powered grain mills and water pumps. These windmills became known as Panemone windmills.

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STEAM POWER AND THE INDUSTRIAL REVOLUTION

In the 17th century AD, came a transformational source of energy for human use: the power of steam. During this time, major industrialization took place, and moved Europe and America away from agrarian economies towards new manufacturing processes. Later it became known as the First Industrial Revolution. While the industrial revolution was a time of many important inventions, the invention of the first steam engine was an important driving factor behind it.

A steam engine is essentially a machine that converts the heat energy produced by steam into mechanical energy. This conversion starts with simply boiling water. To heat the water, coal is put in a firebox, on top of which a tank of water, known as a boiler, is placed. The coal is lit, and the fire starts to heat up the water. Once the water reaches its boiling point, it starts giving off steam. This steam is transported into a cylinder, and in turn pushes a piston back and forth, generating mechanical energy. This back and forth of the piston can have several uses, for example if connected to the wheels, it could be used to power a steam locomotive.

This history of its discovery, commonly believed to be in the eighteenth century by an English engineer, actually dates back to first century AD, Greece. Hero of Alexandria, a Greek inventor, created the first means of converting steam into motion. He designed a novelty known as the aeolipile. It was a hollowed-out sphere with small tubes coming out of the center on opposite sides. The sphere itself was held up by two other tubes, which led down to a cauldron containing water. Below this cauldron was a fire which heated the water, and the steam produced by the water would travel up the tubes into the sphere. The tubes coming out of the center of the sphere would release this steam and the movement of steam inside the sphere would cause it to rotate. Hero's work 'Pneumatica' contained descriptions about machines working on air, steam, or water pressure. In this he described this invention as follows:

No. 50. The Steam-Engine.

PLACE a cauldron over a fire: a ball shall revolve on a pivot. A fire is ignited under a cauldron, A B, (fig. 50), containing water, and covered at the mouth by the lid C D; with this the bent tube E F G communicates, the extremity of the tube being fitted into a hollow ball, H K. Opposite to the extremity G place a pivot, L M, resting on the lid C D; and let the ball contain two bent pipes, communicating with it at the opposite extremities of a diameter, and bent in opposite directions, the bends being at right angles and across the lines F G, L M. As the cauldron gets hot it will be found that the steam, entering the ball through E F G, passes out through the bent tubes towards the lid, and causes the ball to revolve, as in the case of the dancing figures.

However, this invention was merely a novelty. Later, in 1698, an English engineer and inventor

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by the name Thomas Savery built the first steam-powered machine. In 17th century Europe, coal had replaced wood as the main source of fuel. This meant that mining had to be done more, and the mines itself became deeper. A large issue with this was flooding due to underground water sources being penetrated. To solve this, Thomas Savery designed a machine that first heated water in a chamber to create steam. As this heated up the chamber considerably, cold water was thrown on the closed chamber to cool it, which in turn cooled the steam, creating a vacuum. As this chamber had a pipe leading down to the water in the mine, once it was opened the vacuum sucked the water upwards and out of the mine. This invention became known as 'Miner's friend'. 13 years later, another English engineer and partner of Savery named Thomas Newcomen brought about major improvements to the steam pump. He invented the atmospheric engine, which was the first commercially successful engine that used the piston and cylinder. Two major flaws with the design of Savery's steam pump was that it couldn't have been more than around 30 feet above water level, as it relied solely on atmospheric pressure, and that it was risky due to the high pressures the boiler would be operating at. Newcomen increased the overall efficiency of the pump by creating a partial vacuum (similarly through cooling the cylinder), however instead this pump used the force of the vacuum to pull a piston downwards. The piston was attached to a suspended beam, on the other side of which was a pump, which when raised would carry water out with it. The weight on the other side of them beam would then bring the piston back up, or reset it, and the process would repeat. This became a major success, however there were still drawbacks. Even after the improvement, it was still highly inefficient. It required a constant flow of cold water for cooling, and a constant energy source for heating. The major breakthrough came in 1765 by Scottish engineer James Watt. After seeing how much steam Newcomen's pump used up, Watt concluded that to make it more efficient the steam should be condensed separately from the cylinder. This way, the cylinder would remain hot, and it would operate constantly as taking a pause to reheat the cylinder would no longer be necessary. He continued improving his model for the next 15 years, and in 1790, Watt's engine was easy to establish in several locations, and had a number of uses.

Due to its efficiency and usefulness, Watt's steam engine became a driving force behind the Industrial Revolution. It began being used across the United Kingdom, and after a while even the United States. The engine could be used in mining, transportation, as well as factories. It also allowed for factories to be located anywhere, as opposed to near a river due to water being the previous source of power. Due to immense improvement it brought from the previous manufacturing methods, it soon became the dominant source of power, after replacing water and wind. In around 1815, the arrival of steamboats also had a major impact on the industrialization. This is because before steamboats, journeys would take much longer, and could only take place downstream as fighting the current became difficult. This drove industrialization, as goods and

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people were now being transported further and quicker, which increased the general demand for goods, moreover farmers were able to sell their goods elsewhere. It also increased specialization, as specific goods such as sugar and cotton were shipped to the north.

OIL AND TRANSPORT

On August 27 of 1859, the first successful use of a drilling rig on a well drilled mainly to produce oil took place on Oil Creek near Titusville, Pennsylvania. This was led by George Bissell and Edwin L. Drake, and it came to be known as 'Drake's Folly'. While this was the first modern oil well, oil had first been discovered way back in 600 BC, China, and was transported in pipelines made from bamboo. It was not long after, that human ingenuity created engines, that could instead of being run by stem from coal, could directly be run from the energy released by igniting oil. By the end of the 19th century and throughout the 20th century, oil became the primary source of driving human mobility, whether on land, on water, or finally with the invention of airplanes, in the sky.

ELECTRICAL ENERGY

In today's world, the most commonly known source of energy is electrical energy. Without electrical energy, the human world as it exists today, would collapse.

The idea of electricity had been around for a long time. The discovery of static electricity actually dates back to 600 BC ancient Greece.

Electricity is actually called a secondary source of energy, as it is derived from the primary sources, such as hydropower or sunlight.

Up until the 18th century, till Benjamin Franklin's interest in electricity, the main idea of electricity was related to static electricity. Benjamin Franklin came up with the idea that there are positive and negative elements to it. He conducted an experiment with a kite which he attached to a key and flew it out during a storm, which conducted the electricity from the lightning down to the key. This proved his idea of lightning being a form of electricity that flowed between positive and negative. As time progressed from Franklin's time, scientific knowledge about how electricity works started furthering and its scientific and commercial development began.

An important advancement in the development of electricity was the invention of the first, continuous, reproducible source of electrical current: the battery. In 1799, Alessandro Volta, a philosophy professor at Pavia, stacked alternating discs of zinc and copper, and separated each

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with a cloth soaked in a weak acid (this was known as the Voltaic pile). A continuous current was produced by a wire attached to each end of the pile. This was an important invention, as this battery inspired a series of other inventions. The first battery available for mass production was invented in 1802, and later the rechargeable battery in 1836. The main uses of these batteries involved telegraphy, arc lighting systems and metal electroplating.

Also, among the first sources of electrical energy, was surprisingly the direct energy of the sun, with a particularly interesting backstory. The history of it began in 1839 with the discover of the photovoltaic effect. Behind this discovery was French physicist, Alexander Edmond Becquerel. He discovered this at the mere age of 19 in his father's laboratory when light from illuminated silver chloride struck a platinum electrode and generated voltage. The application of this effect first came about by Auguste Mouchout, a mathematics instructor at the Lyce de Tours. He is known for being the first to convert solar radiation into mechanical power and started work for this in the year 1860. By 1865, he successfully operated a small steam engine using his apparatus. In 1873, the first 'real' working solar module was created by American inventor, Charles Edgar Fritts. While Mouchout's invention was referred to as the first successful conversion of solar radiation to mechanical power, this module was declared by Werner von Siemens as the first 'direct conversion of the energy of light into electrical energy'.

The late 19th century was an important period in the advanced of electrical energy. The first, long lasting incandescent light bulb was developed by Thomas Edison in 1879.

Along with solar power, hydroelectricity also first came into use. While the idea of hydropower is about 2000 years old, when falling water was first used by the Greeks to turn water wheels for grinding wheat into flour, it wasn't until September 30th of 1882 that the first hydroelectric power plant began operations. This took place along the Fox River in Appleton, Wisconsin, and was initiated by paper manufacturer H.F. Rogers, who was able to generate sufficient power to run the plant, a nearby building, and his house.

As new, more stable batteries were being invented and improved, an equally important development was simultaneously taking place. The development of electricity through magnetism. Along with Michael Faraday's contributions, mainly his discovery of electromagnetic induction, Humphry Davy and his research team were able to generate an electrical force that would keep going as long as there was movement between a coil and a magnet, which became known as a generator. The process switched around led to the invention of the motor.

These generators came in two forms, one that generated direct current (DC), and one that generated an alternating current (AC). From around the 1870s, both these generators found use in

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society. AC generators were used for a type of outdoor lighting known as the Jablochkoff Candle. On the other hand, the main reason DC was still used was the lack of a suitable AC motor available. Edison designed a large central power plant, consisting of DC generators known as dynamos (improved versions of the original DC generators, capable of delivering power for industry, brought about by Werner von Siemens). The first of these systems were introduced at Pearl street station in New York, where Edison and his team designed the largest dynamo at the time. It was nicknamed Jumbo, and they built six of these for the plant at the station.

This distribution of power gained a lot of commercial success, however there was a major drawback. Edison made use of 120-volt bulbs and motors, and his system was only able to cover an area of 1 square mile. Inventors hence began looking for ways to increase distance of transmission. AC motors were the obvious alternative, as they had the capability to step-up (increase) and step-down (decrease) the voltage through the use of a transformer. However, at the time, there was no design for an appropriate AC motor.

This is when Nikola Tesla stepped in. Tesla was a Serbian immigrant who devised an AC motor and a generator, using polyphase AC. This type of AC current makes use of several AC flows and combines them into a single AC output. This became known as the Tesla motor and was introduced in 1887. It enabled the transmission of high voltages over long distances, for a relatively cheap price. This lowered costs and increased demand for electricity in homes.

Once the distribution for electricity was underway, the generation methods began getting more refined and efficient.

In July 1904, the first ever geothermal power generator was tested. Once again, the use of geothermal energy dates back a long time, to the Paleolithic era, in fact, when hot springs were used for bathing purposes. The first breakthrough in terms of power generation, however, was brought about by Italian scientist Piero Ginori Conti. After the testing proved successful (it was able to light 5 lightbulbs), he moved on to develop it into the first ever geothermal power plant in Larderello, Italy in 1911.

Finally, most recently, came the introduction of nuclear power. While its early years were spent into the creation of atomic bombs and other nuclear weaponry, its use of electricity generation came about in around 1954. On June 27 of this year, the Obninsk Nuclear Power Plant became the first ever nuclear power plant to produce electricity industrially. Situated in the 'Science City' of Obninsk, Kaluga Oblast, it generated around 5 MW of electricity. 1970s onwards, nuclear power increased rapidly as more and more plants were being created.

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ENERGY TODAY

The central role of energy, especially electrical energy, to human civilization is such that modern societies would collapse without it. However, there are consequences to this pervasiveness of energy. It is ironic that, in the long run, energy sources such as coal and hydrocarbons, that have enabled human societies to flourish, pose the greatest threat to human existence from pollution and global warming. The main challenges in moving to cleaner energy sources like solar, wind and hydro are cost and unreliability of sunlight, wind, river-flow etc. The primary focus of energy engineers now needs to be to overcome the challenges of cost, storage during high generation to use during low generation periods through larger, cheaper and more reliable batteries, larger grid networks etc. Policy-makers and governments have a large role to play as well, to drive replacement of hydrocarbons and coal with cleaner energy, through international co-operation, phasing out of petrol- and diesel-powered cars, placing quotas on the production levels of suppliers, etc.

Humans have displayed great ingenuity in harnessing energy for their short-term gains. Engineers and governments now need to come together to use the same ingenuity to drive a change in our energy sources for the long term to benefit the generations to come.

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