The Soul of Solar Energy: Augustin Mouchot

It was a typical, cold January morning in Alençon, France. The year was 1860. High school mathematics teacher, Augustin Mouchot shivered as he reluctantly rolled out of bed. The thought of having to stoke the stove and heat the water for his morning washing routine did not thrill him. Besides, he needed to conserve the coal, which was growing scarce in his homeland and becoming expensive these days. As Augustin arose in the chill of the dawn, his thoughts drifted to what he had just been reading about the energy of the sun. Physicist Claude Pouillet had written that every square meter of the Earth's surface receives about 10 Calories of energy every minute. Augustin chuckled, "Not a very useful fact on a cloudy day like today!" Then, a flash of inspiration crossed his mind: "It's not cloudy every day. Wouldn't it be possible to heat enough water with the sun's light and spare the fire that is only meant to heat the house?" While he made the last preparations to teach his geometry class, he could not get his mind off the energy issue. The thought kept coming back to him, "The issue of energy is bigger than the needs of my household—I should try to do something about it."

Over the next few months, Augustin immersed himself in his new project of building a solar energy collector despite having to teach his regular classes. He reviewed what he had already learned about harnessing the energy of the sun. Reasoning that copper is a good conductor of heat and a black surface is a good absorber of heat, he would have to contain the water in a copper vessel that was painted black. The water would then obtain its heat from the copper. To prevent the heat from escaping out the back, he thought it better to mount the unit on a bad conductor of heat, and to prevent the heat from escaping out the front, he would cover it with glass to trap the heat that was absorbed inside. "What a great idea!" he thought. "But, in order to get more heat, I would have to make a bigger absorber—not very practical…. On the other hand, what if I put a mirror on the outside to reflect more of the sun's rays onto the absorber? That way I could make the device smaller."

Soon, Augustin had completed the construction of his first solar water heater, which was capable of holding three litres of water. Lucky for him, it happened to be a cloudless day! Excitedly, he placed the boiler and mirror in the direct sunlight. To his amazement, the water, which he had initially measured to be 15 degrees, boiled in just an hour and a half. From then on—on sunny days—Augustin saved himself the bother and the expense of coal-heated water when he bathed.

With further improvements to the solar heaters, Augustin was able to bring water to a boil more quickly. He began to ponder new and bigger possibilities. "Perhaps, I could design solar steam generators to power machines, like the steam engines used in industry," he thought. Coal was the main fuel for industry, but France was already experiencing a shortage of this expensive resource. "When the supply of coal eventually runs out," he reasoned, "then using the energy of the sun might be our only available alternative." Augustin thought that his idea of a solar-powered engine could contribute to the well-being and progress of the entire nation.

Harnessing the sun's energy became a fascination and all-consuming preoccupation for Augustin. "We need to heat so many things in everyday life—water, home, food…. Why, of course, food!" So, the mathematics teacher turned cook prepared a delicious stew for dinner and cooked it in his solar heater. The solar heater had become a solar cooker.

Over the next several years, Augustin continued to work on his solar energy idea, employing his natural creativity and his university training in physics and mathematics. He especially wanted to develop a solar engine that could drive all kinds of mechanical devices used in industry and agriculture. By 1866, he was ready to launch his idea in the public domain. Political support would be advantageous at this strategic moment. His connection with Jean-Baptiste Verchère de Reffye, Ordnance Officer of the Imperial Workshop at Meudon, who had influence with the Emperor, proved

useful. De Reffye persuaded Napoleon III to attend a demonstration of Augustin's new solar engine. The Emperor was so impressed with the invention that he immediately granted Augustin the full assistance of the Imperial Workshop. With this level of technical assistance, the inventor could forge ahead.

By the next year, Augustin had perfected a solar engine capable of driving an Archimedean screw that could be used to pump water for irrigation. In its design, he found that the main considerations were the geometrical arrangement of the heat absorber and the mirror. The best shape for the mirror was an open-ended cone, with the curious mathematical name of "frustocone," that focused the sun's rays along a line on its axis where a narrow cylindrical heat absorber, which contained the steam generator, was located. The device was installed in Paris, and at that occasion, Augustin remarked, "The problem of the steam-driven solar machine has been completely solved. We should judge from this result that the engine would best be used in tropical regions, where we should go to test the device in practical situations."

A logical testing location for Augustin was Algeria, a French colony in the tropics, conquered in 1830. Of course, he still had to continue in his teaching position, which entailed restrictions of time and finances. Augustin quickly realized that in order to be able to reach his goals, he would need to obtain major government funding and leave from his teaching duties. Just when he was poised to take his final, strategic steps to obtain funding, war broke out between France and Germany. It was 1870. The war was fast and furious, and, by the next year, France had been defeated, Napoleon III had been sent into exile, and a new government was formed—the French Third Republic. Many of the arrangements that Augustin had had in place vanished, the notable solar machine that he had set up in Paris was nowhere to be found, and the technical support from the Imperial Workshop was suspended. It was a monumental setback for Augustin, but he was not discouraged.

From 1871, then, Augustin set out to lay the groundwork for his solar dreams in other ways: by writing about his work and applying for patents. Astonishingly, while still being a full-time mathematics teacher, he managed to complete a 233-page volume, which he entitled *Solar Energy and its Industrial Applications*. The book advertised his dream of, in his words, "finding a convenient way to collect and use sunlight directly for the benefit of agriculture and industry in the hottest regions of the world." In order to establish the importance of his ideas, he was able to register three patents for his designs, and by 1876, he had achieved sufficient fame with his work that the government awarded him a silver medal. Most importantly, though, that year Augustin was granted leave with pay from his teaching position by the government so that he could devote all of his time to his work on solar energy in the tropics. His dream would come true at last! In the very next year, Augustin Mouchot set sail for Algeria—financed by a huge government grant of 10,000 francs.

In Algeria, he invented and tested many versions of his solar energy devices for many different useful purposes. Perfecting his solar cooker proved strategic for the military, which could better conceal their positions as they prepared their food in smoke-free heaters. His report on his inventions to the government impressed the General Council so much that Augustin was granted 5,000 francs to design and build the largest solar collector ever to be built. It was to be exhibited at the Paris World Fair of 1878.

For the difficult task of building the giant solar collector, Augustin placed a talented, young engineer, Abel Pifre, in charge. Although the World Fair took place between May 1 and October 31, the mirror was completed only by the second of September. At that time, the collector was able to bring 70 litres of water to a boil in half an hour and generate steam pressure of six atmospheres. Augustin and Abel used the steam generator to drive an ice-making machine, using the hot sun's rays to produce a block of ice. The people at the fair marvelled at the phenomenon—producing ice from heat! The jury of the Fair was so impressed that it awarded Augustin the gold medal in his category, and the Ministry of Agriculture and Trade, not to be outdone, named him Knight of the Legion of Honour.

Not wanting to waste the opportunity provided by the honours, Augustin applied for government funding for a new mission to Algeria immediately after the World Fair. Inexplicably, and to his dismay, the government granted him only 5,000 francs. His disappointment at the inadequate support, however, did not keep him from pursuing his mission, and he departed for Algeria, once again, to perform new experiments.

Ever optimistic, he, once more, returned to France to apply for a large amount of new funding. This time, his request was denied outright. What a letdown for Augustin! The government, having commissioned a study on the economic viability of solar energy, had concluded that there was no justification for further research. National and global events were fast eroding Augustin's aspirations. More coal deposits had been discovered in eastern France, making coal more abundant and less expensive, and lessening the pressure to develop other energy sources. In the USA, oil, having been discovered in 1859, was already being harnessed as a fuel to supply energy needs. Ironically, the 1878 World Fair, where Augustin had gained his international stature, marked the unveiling of the internal combustion engine. This proved to be the final undoing of Augustin's fading solar-energy dream.

Could the situation get any worse? It did. Augustin's leave from teaching was to expire in the following year, but circumstances prevented him even from resuming his position, as a serious bacterial infection, which he had contracted in Algeria, had left him deaf. A small consolation was that his disability allowed him to apply for a pension, which was fortunate, as he had already reached the age of 55 years.

Deteriorating eyesight and meagre finances plagued his retirement. Yet, he was able to complete and publish an important book on geometry in 1892, for which he received a prize from the Science Academy. Thereafter, he receded from the public eye. In 1907, a member of the Science Academy discovered that Augustin was living in deep misery, and the Academy generously granted him an additional pension of 1,200 francs.

One day, the lonely Augustin received a visitor. It was the military doctor Félix Pasteur from Algeria. The doctor told him about the use of solar water heaters in hospitals and military barracks there and expressed appreciation to him for this valuable contribution. It was one of the last satisfying joys Augustin was to experience. On October 4, 1912, eighty-seven-year-old Augustin Mouchot, no longer capable of even picking up his pension from the post box, died penniless and alone.

How the coincidental interplay of economics, politics, and history can crush humanitarian ideals and decimate noble dreams!

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