MAD LIKE TESLA

Underdog Inventors
and their **Relentless Pursuit**
of Clean Energy

TYLER HAMILTON

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There has been so much thought put into anticipating, avoiding, and destroying tornadoes that I became quite intrigued in early 2007 when I received the following email from a gentleman named Brian Monrad, a lawyer who was writing on behalf of a friend. "An engineer in Sarnia, Ontario, says he can create an artificial tornado and use it to produce electricity," he wrote. "Three top scientists from Oxford, Cambridge, and MIT agree that this is a real possibility and have joined the advisory board." Curiosity got the best of me, and a week later I found myself making the four-hour trek to Sarnia, where I was welcomed into the home of retired refinery engineer Louis Michaud, inventor of the patented atmospheric vortex engine concept.

GIVING IT A WHIRL

Michaud, a grandfather of four, is a slight and soft-spoken man in his late 60s who lives in a 1950s-style bungalow in a quiet area. Heavily industrialized Sarnia — nicknamed Chemical Valley because of the high density of chemical companies and refineries it hosts — neighbors a town called Petrolia, home to North America's first commercial oil well and touted by locals as the cradle of the global oil industry. Michaud worked more than 25 years there as a process control engineer at Imperial Oil, which is majority owned by ExxonMobil and ranks as the largest petroleum company in Canada. A spare-time inventor for most of his career, it was only after Michaud retired in 2006 that he could throw himself into the idea of extracting energy from tornadoes. It was then that he formed a company called AVEtec Energy with an aim to commercializing his unique vortex engine.

Minutes after we met, he took me to his garage to demonstrate a small-scale version of what he'd like to build, one day, on a massive scale. In his garage, between hanging bicycles and a tool bench, sat a hollow plywood cylinder about two feet high and nearly four feet in diameter. It had a round opening at the top, just big enough to stick your head into. At the bottom was a heating element connected to a small propane tank. Michaud fired up the propane heater and then lit a couple of pieces of saltpetre to get them smoking. As the heater began warming the bottom of the cylinder the air within it began to rise, carrying with it the smoke from the burning saltpetre. Within seconds, the rising saltpetre smoke started swirling and took on the shape of a vortex — a miniature tornado. A few minutes later, Michaud turned off the propane and opened the door to his garage to let out all the smoke that had accumulated inside. A woman walking her dog passed by on the sidewalk and looked on curiously; she probably thought we were smoking marijuana in the garage. I felt like Jeff Spicoli in *Fast Times at Ridgemont High*.

The demonstration, though interesting, could have easily been a high-school science fair experiment. Back inside the house, Michaud fixed me a cup of tea and began explaining his vision. The garage demonstration, he said, was just to show how heated air can be made to spiral as it rises. His idea is to build a structure that would support the creation and control of a tornado-like vortex that stretches many kilometers into the sky and spins at more than 300 kilometers per hour, as powerful as an F4 tornado capable of serious destruction. Why on Earth would anyone want to do such a thing? To generate clean electricity. A tornado needs to sweep in warm air from ground level in order to survive, so any supporting base structure would need air-intake ducts, and those ducts could be equipped with turbines. The powerful suction of air through those ducts would spin the turbines and generate electricity, Michaud explained. "I'm talking about a 200-megawatt device here," he said. "It would be 200 meters across and the vortex would be one to 20 kilometers high. It would have 10 turbines installed around its base, each producing 20 megawatts."

The key, he said, is to find a large source of low-grade heat that can get the tornado going, just like the propane heater he used in his garage prototype. One dependable source is waste heat from thermal power plants. Nuclear and coal power stations, as well as certain types of natural gas–fired plants, convert only one-third of their fuel into electricity. The rest of the energy in that fuel gets rejected as waste heat. That means a plant that produces 500 megawatts of electricity is throwing away the energy-equivalent of 1,000 megawatts of heat. That heat is released into the air using dry or wet cooling processes, or it can be absorbed into water and discharged into a large lake. It's a ridiculous situation, said Michaud. "We produce warm, humid air and just throw it away. In fact, we put fans on top of these cooling towers to get rid of the air, and we use a lot of power to drive the fans." He's not kidding: just running fans alone on a mechanical draft cooling tower eats up about three percent of a generating station's power output.[6] Michaud said that waste heat can be used to fuel a man-made tornado capable of generating 200 megawatts, which would improve the efficiency of a thermal power plant by 40 percent and offset the need for and cost of a cooling tower. Presumably, waste heat from solar thermal power plants could also be used. "The process could be developed with relatively little engineering effort," according to Michaud's business plan.

All of this might sound impossibly ambitious, but it's just the start. Longer term, Michaud sees the potential of building his vortex engines along tropical coastlines or on floating ocean platforms along the equator. Heat could be endlessly extracted from tropical waters as a way to sustain power-producing tornados. These same warm waters, which can reach as high as 32 degrees Celsius, are the source of energy for hurricanes and spontaneously appearing water spouts. "The passage of a hurricane can reduce surface temperature by up to 5 degrees Celsius," said Michaud. "They basically carry heat away from the surface."

Man-made tornadoes would achieve the same goal, drawing heat from the surface through the center of their vortex and dumping it into the upper atmosphere where it's more than 60 degrees Celsius cooler and the heat can more easily radiate into space, beyond the confines of the greenhouse effect. The only difference is that man-made tornadoes could generate electricity at the same time. In a way, Michaud's vortex engines would operate like massive air conditioners for a warming planet but ones that produce, rather than consume, electricity. "It's the first energy source to contribute to global cooling, not global warming," touts Michaud's business plan. Two months after meeting Michaud, I wrote a story about his invention in the *Toronto Star*.[7] It captured the attention of many readers, including Steven Levitt, professor of economics at the University of Chicago and co-author of the bestselling books *Freakonomics* and *SuperFreakonomics*. "This is probably too good to be true, but all you need is one big idea like this to work," he wrote in his *New York Times* blog. "Technology and human ingenuity have solved just about every problem we've faced so far; there is no obvious reason why global warming shouldn't succumb as well."[8]

WHAT GOES UP . . .

The idea of harnessing heat from warm ocean waters has been around for more than a century. As mentioned in the introduction, Nikola Tesla wrote in detail about extracting heat from the ocean to generate electricity, a method of power generation called ocean thermal energy conversion (OTEC) that Lockheed Martin has pursued for the last four decades. Another idea that has been around for several decades is the manipulation of atmospheric convection to produce electricity, which is essentially what Michaud is attempting. Convection is one of three major ways that energy is transferred between the Earth's surface and the atmosphere. The other two are conduction and radiation. Conduction happens when heat moves from a higher temperature substance to a lower temperature substance, for example, from warm air into cold soil or warm soil into cold air. Radiation is a transfer of heat through electromagnetic waves, which you feel when the sunlight hits your face.

Convection, on the other hand, occurs when hot less-dense air rises and cold dense air sinks. Convection is why a hot-air balloon rises, and why macaroni in a pot of boiling water moves up and down — the hot water closest to the heating element rises to the surface, cools, and then sinks back down in a constant churning motion. (The convection, or heat transfer, gets stronger as the temperature difference between the bottom of the pot and the surface of the water gets greater.) The lower atmosphere of our planet behaves, generally, in a similar way. The sun heats the surface, causing surface air to warm up and rise to much cooler layers of the atmosphere, where the air cools and descends back to the surface.

This is all somewhat orderly chaos until some sort of disturbance leads to storms, which can trigger the formation of tornadoes. With the right wind conditions, a rising pocket of warm humid air can begin to swirl, resulting in a spinning column that narrows as it starts drawing in warm air from the ground. As it narrows, it gathers speed and strength — the same way a figure skater can spin faster by pulling her arms tight against her body. The powerful tornado that eventually forms becomes a path of least resistance through which warm air on the ground can travel kilometers into the sky to the sub-zero temperatures of the upper troposphere. By sub-zero, I mean between –30 and –60 degrees Celsius. (Keep in mind, this is a simple explanation of an otherwise complex weather process that is still not fully understood. But the role that convection plays is clear.)

One of the first individuals to think up a way to capture the energy from this convective process, and certainly the first person to receive a patent on a design, was a Frenchman by the name of Edgard Nazare. Not much is known about Nazare, but it was between 1940 and 1960 that the French scientist, stationed at the time in Algeria, observed small sand tornadoes called dust devils in the south Saharan desert. Nazare, an aeronautical engineer and specialist in fluid dynamics, was captivated by the natural forces that caused these sand twisters to form. Convinced it was possible to replicate and control the process, he imagined a man-made apparatus called an "aerothermal power station" that could draw in warm ambient air from the desert floor and coax it to spin and accelerate as it ascended through a 300-meter-tall tower structure.

The tower narrowed at its center, forcing the air to start swirling — the same way water starts to spin as it goes down a drain. As with Michaud's vortex engine, Nazare's cyclone generator would produce electricity from turbines installed within the tower.

Nazare received a French patent for his invention in 1964, and while he championed the idea throughout his career, his efforts were met with resistance and ridicule. He became increasingly frustrated watching France aggressively pursue nuclear power while it ignored what he considered a much safer and morally superior technology. "Why do we systematically ignore the proposition to study aerothermal power stations? Every new technology has question marks," Nazare lamented in France's *L'Ére Nouvelle*, an obscure magazine that he regularly contributed to throughout the 1980s and '90s until his death in 1998.[9] As discouraged as he was, Nazare did prove to be an inspiration for others.

In the early 1980s, for example, the German government funded the construction of a "solar chimney" in Manzanares, a rural municipality about a one-hour drive from Spain's capital, Madrid. The $5-million pilot project didn't create tornadoes, but it did take advantage of convection as a way to generate electricity, in this case up to 60 kilowatts, or enough to power as much as 600 incandescent light bulbs. The design was simple, if not very practical. An area the size of eight NFL football fields was blanketed with a transparent sheet of plastic, just one-tenth of a millimeter thick. A grid of metal poles lifted the plastic from the ground, just high enough to walk underneath. At the center of this plastic-covered area was a circular metal chimney about 200 meters high and 10 meters in diameter. The chimney had a turbine, similar to a wind turbine, installed in the opening of its base.

During the day, sunlight would shine through the plastic sheet and heat up the ground, causing air trapped between the ground and the plastic to warm up by about 20 degrees Celsius. The plastic created a greenhouse effect. The warm, expanding air would then be channeled through the chimney, reaching speeds of up to 50 kilometers an hour. In essence, the chimney became a vertical wind tunnel. Air rushing straight up the chimney would spin an electricity-generating turbine installed at the base. The pilot project worked for about eight years until the chimney support wires rusted out and the chimney was blown over in a storm, but it did prove that the concept was scientifically sound. In fact, the solar chimney even produced electricity at night. The sun would heat the ground during the day, and the heat, stored in the soil, would continue to radiate from the ground in the evening, warming up the air under the plastic sheets and sustaining the upward flow of air through the chimney.

Overall, the solar chimney concept has much to offer. It is unique in its ability to convert low-grade heat into usable energy. A system can be built using cheap and abundant materials, such as plastic and metal. It is simple to operate and maintain. It can supply a certain amount of steady (baseload) power. It also doesn't require fancy solar cells, complex mirrors, or expensive water-cooling systems. But the approach has its problems as well. To get meaningful amounts of power out of such a system — that is, to get megawatts instead of kilowatts — requires construction of a substantially taller chimney. The taller the chimney, the stronger the updraft; the stronger the updraft, the more power you can generate. (It's similar, in a way, to water power. If you have two waterfalls of similar volume, the taller of the two has the potential to produce more power.)

In 2001, a company called EnviroMission announced that it planned to build a 200-megawatt solar chimney in southwest Australia that could generate 4,000 times more power than the Manzanares system. But to get that kind of power, EnviroMission must construct a solar chimney that's 130 meters in diameter and 1,000 *meters tall*, which is more than 11 times the height of the Statue of Liberty and nearly twice as tall as Toronto's CN Tower. Keep in mind that the world's tallest structure, the Burj Khalifa skyscraper in Dubai, is 828 meters tall, meaning EnviroMission would have to break a world record for its solar chimney to become a reality. Also, to create enough warm air to flow through that chimney will require a plastic- or glass-covered solar collection area of up to 35 square kilometers, roughly equivalent to

5,000 NFL football fields. The project is expected to cost nearly $1 billion.

EnviroMission has two more solar chimney projects planned for Arizona and, in 2011, secured $30 million in funding to cover early development costs. Solar chimneys are also being considered in other parts of the world. Projects are on the drawing board in the European Union and Africa, including a solar chimney in Namibia dubbed "Greentower" that would reach 1.5 kilometers into the sky and require a solar collecting greenhouse covering 37 square kilometers. None of these commercial-scale projects have reached construction phase, and there's no certainty they will.

ENTER THE VORTEX

Louis Michaud wasn't aware of the Manzanares project until a year or two after it was built, but he was quite familiar with the solar chimney concept. The idea had been floating around since the early 1900s, when Spanish Colonel Isidoro Cabanyes first described his "solar engine project" in a magazine article published in 1903.[10] In 1931, German author Walter de Haas, writing under the pseudonym Hanns Günther, proposed the use of solar chimneys — also known as solar updraft towers — as a way to generate electricity in a world that he believed would run out of coal.[11] Michaud was delighted to see the Manzanares project built, because it demonstrated how warm, expanding air could be converted into mechanical energy as it is carried upward by convection. But in his mind, solar chimneys are inefficient and not very practical, specifically because of the dramatic heights needed to generate megawatts of power. "The cost of the chimney is just incredible," he once told me.

This is part of the reason Michaud, some time in the mid-1970s and while working in a Quebec paper mill, turned to the idea of creating tornadoes to generate electricity. It was a hobby, really, a personal project that grew out of his side interest in meteorology and his on-the-job exposure to convective processes in an industrial setting. He knew that tremendous amounts of energy could be harnessed through atmospheric convection and saw the solar chimney as one way of doing it. At one point, he even considered the use of a chimney-like tube held high in the sky by a blimp, but it just wasn't practical or efficient enough. Then it struck him: tornadoes are their own chimneys. Not only that, these self-swirling columns of air can stretch several kilometers high.

If you think about it, the purpose of a physical chimney is to prevent cooler, higher-pressure ambient air on the outside from mixing with lower-pressure warm air as it flows up through it. The high-pressure air desperately wants to mix with the low-pressure air, but if this happens it will weaken or kill the convection process. The beautiful thing about a vortex is that it doesn't need this physical separation. Instead, the centrifugal force created from its rapid spinning makes an air wall that effectively pushes back on the surrounding ambient air that's trying to muscle its way inside. As a result, the column of warm air within the vortex can rise to great heights with little interruption. Michaud, realizing that the sky was literally the limit, turned his attention to making tornadoes.

It was soon after this realization that Michaud discovered the work of Edgard Nazare. Michaud was intrigued by Nazare's ideas and began corresponding with the French scientist in 1973 and through much of that decade. Back then, of course, they didn't have the advantage of the Internet and email, so their exchanges were in no way frequent. In fact, there was little contact between the two inventors during much of 1980s. Michaud was hired as a process control engineer at Imperial Oil (known under the trade name ESSO) and immersed himself in his new refinery job, to the point that he stopped publishing research papers and put aside his work on "tornado power." It still occupied his mind, however, and the new job proved crucial to refining his ideas. "One of the reasons I went to work at ESSO is that the petroleum industry had a lot of applicable techniques for what I was studying," Michaud recalled during an interview in spring 2010. He said a large petroleum refinery might have half a dozen cracking furnaces, 10 compressors, and 6 distillation towers. It was the perfect learning ground. "You're able to use those assets, and surprisingly there are a lot of convection processes there. You end up learning from the real world, rather than just computer simulations."

Fast forward to 1992. Michaud checked the mail one day and found a large brown envelope sent to him by Nazare. "It was all his papers," said Michaud, who was in his late 40s at the time and didn't realize that Nazare was well into his 70s. "He was passing on the torch to me, I guess. He figured I was the person most likely to bring the concept forward." Michaud believed that Nazare, having worked on the concept for most of his life, was disappointed that it never gained mainstream acceptance. "He was looked at as a bit of an odd ball. He had to self-publish and after a while got frustrated. It was good for me to see what happened to him, because I realized I had to make sure I explained the rationale behind what I was proposing." Michaud said one tool Nazare never had during his career was the Internet, which would have made his work more accessible and given him a way to collaborate with like-minded individuals around the world. Without that community, Nazare remained a scientific renegade within France's conservative scientific establishment.

Michaud felt a personal obligation to Nazare to carry the concept forward. He continued to refine his ideas through the 1990s, but it was only during the lead-up to his retirement in the first few years of this century that he began to promote the commercial potential of tornado power. He drew up a detailed design for a utility-scale vortex engine in 2001 and filed for a patent the same year.[12] In 2005, a year before his retirement, he created a website, VortexEngine.ca, and populated it with as much explanatory information as possible as part of a larger effort to raise awareness of the idea. He developed a business plan and started work on a small-scale prototype. Michaud also knew he needed some credible backing, so he reached out to the world's top climate and atmospheric scientists, many of whom agreed to be informal advisors. One of those scientists is leading hurricane expert Kerry Emanuel, a professor of meteorology at the Massachusetts Institute of Technology. Emanuel, who has read Michaud's papers and is in occasional email contact with the Sarnia engineer, said in an interview that there's no doubt in his mind the vortex engine will work. "It's mechanically very simple, and that's the beauty of it," he said. "One of the nice things is that it achieves a thermodynamic efficiency you wouldn't expect, with the advantage that it can operate on low-temperature waste heat." The proposed Australian solar chimney, for example, can convert at most about 3 percent of the thermal energy it collects into electrical energy, while Michaud's vortex engine can convert closer to 20 percent. "So, for sure, this is something worth exploring," said Emanuel.

FORGING ON

By the time I met Michaud in spring 2007, he was working full time on his vortex engine and trying to raise money to construct prototypes that were much larger than the small demo in his garage. He had managed, through an Ontario government program, to partner up with the University of Western Ontario to run computer simulations, but that wouldn't be enough to excite investors. People want to see real-life tornadoes, not computer screens. But taking his idea from a one-meter-diameter garage prototype to a commercial power facility up to 200 meters across? Building a vortex engine capable of producing a tornado over a kilometer high? Well, that wouldn't so be easy. For one, it requires a significant injection of capital. Just building a four-meter-diameter prototype would likely cost $300,000. A pre-commercial model between 10 and 50 meters in diameter, connected to a large steam source and equipped with small power-generating turbines, might cost several millions of dollars. At this size, Michaud has wondered whether an amusement park, such as Walt Disney World, might want to build one of his tornado machines as a tourist attraction.

Any larger and it gets *really* expensive, though still a deal compared to a solar chimney. Michaud has pegged the price of a full-scale facility about 100 meters in diameter at roughly $60 million. At that size, it would generate 200 megawatts of power using waste heat ejected from a thermal power plant fueled by coal, natural gas, or uranium.[13] To build an even larger stand-alone facility that could extract heat from tropical ocean waters would cost north of $200 million. This tropical facility would be capable of generating up to 500 megawatts and would have a diameter of 200 meters, allowing for the creation of a monster F4 or F5 tornado.

It sounds like a lot of money and it sounds a little — well, maybe a lot — crazy. But what should matter more is the payoff. If you believe Michaud's calculations, his atmospheric vortex engine is an economic slam dunk. He figures it could generate electricity for less than 6 cents per kilowatt-hour, and possibly as low as 3 cents per kilowatt-hour, making it a better deal than nuclear and natural gas, far cheaper than renewables such as wind and solar, and competitive with the dirtiest of coal plants. The capital cost of building his vortex engine facility would be about $300,000 per megawatt, or about a quarter of what it would cost to build a new coal plant of the same power output. More than that, it eliminates the need for a conventional cooling tower that, at a new power plant, would cost just as much, if not more, to build. "From an engineering perspective, building this is not really a big deal," said Michaud. He firmly believes his power-generating vortex engine is one of the lowest-cost options for producing electricity, particularly zero-emission electricity.

Since our first meeting in 2007, I've checked in with Michaud occasionally for progress reports. He's still pushing, still networking, still spreading the word, but not much has happened in four years. The largest prototype he has built to date is only four meters in diameter; it was tested in summer 2008 and created twisters more than 12 meters high. Decent enough, but like any new technology that requires an openness of mind and a willingness to take risk, finding the public granters or private investors who can take the project to the next level has proved to be a major hurdle, at least for now. Of course, there are some small exceptions. One was a lady in British Columbia who read about Michaud's tornado power concept in the San Francisco–based magazine *Ode*. She took a $100 "carbon tax" rebate check issued by the B.C. government and decided to sign it over to Michaud. "I think we should be putting as much money as possible into alternative energy research, so I would like to give my $100 to you for your project," she wrote him.

The media, of course, love Michaud. Who can resist writing about a retiree trying to make powerful tornadoes to supply electricity to towns and cities? Unfortunately for him, coverage hasn't translated into financial support or a willingness on the part of any utility to give his vortex engine a spin. "It's not an incremental step from somebody saying, 'This is interesting' to somebody saying, 'I'm going to invest in this,'" said Michaud. In other words, the vortex engine is fascinating enough to open doors, but too "out there" to get signed commitments. "The utility industry is very conservative. I was contacted by the Tennessee Valley Authority after one article, and the manager of technical innovations there was quite interested. I prepared a presentation and sent it, but once she talked to her boss it was the end of the discussion." Michaud opened up a similar conversation with Alberta power utility TransAlta, which operates a 500-megawatt natural gas plant in Michaud's hometown of Sarnia. It ended the same way after the local business manager escalated the idea to corporate headquarters in Calgary. "The CEO has got to get behind it if it's going to go anywhere," said Michaud. "But once you get past the engineers, the executives aren't interested."

Scientists, on the other hand, seem to gravitate toward the concept. A sign of the times, maybe? Nazare, you'll recall, was shunned in his day by France's scientific community, a time when climate change, peak oil, and energy security in general weren't pressing mainstream concerns. They are now. Michaud had no problem attracting the attention of the U.S. Department of Energy's Sandia National Laboratories. He traveled to New Mexico in January 2009 to present his idea to a room of 10 Sandia scientists eager to learn more. "They were awed," recalled

Michaud. "One of the directors there, Sheldon Tieszen, told me directly he wanted to personally work on this thing." Such a partnership with a respected government lab would have been invaluable to Michaud, and indeed, Sandia applied for funding through ARPA-E — the U.S. government's cash-flush Advanced Research Projects Agency (Energy) — so it could demonstrate Michaud's cyclonic creation as part of a CO_2 capture system that could generate electricity at the same time. Their application was unsuccessful.

ADVANCE PRAISE FOR **MAD LIKE TESLA**

"A brilliantly written page-turner about the 'mad' inventors and entrepreneurs who will become modern day heroes if their efforts can produce energy without changing the earth's climate."
— **James Hoggan**, author of *Climate Cover-Up* and chair of the David Suzuki Foundation

"Hamilton enables us to join the clean energy optimist's club by shining a bright light on humanity's amazing capacity for imagination and invention. Well written, compelling, and inspiring."
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CLIMATE CHANGE. Runaway resource depletion. Life-smothering pollution. It is easy these days to feel hopeless, but there is also reason to be hopeful. This is a time of unprecedented innovation, and an army of scientists, inventors, and entrepreneurs are madly working away trying to solve humanity's most pressing problems. In *Mad Like Tesla*, Tyler Hamilton explores some of the latest and most "out there" energy innovations and the lone runners behind them. Some of their ideas might seem radical, impossible even. But as Hamilton writes, many great inventions were once doubted, dismissed, and ridiculed — only to emerge triumphant.

TYLER HAMILTON is an author, adjunct professor, and award-winning energy and technology writer for the *Toronto Star*, where for six years he has been one of Canada's leading voices on green technology issues and trends through his weekly column. Read his blog at CleanBreak.ca.

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