INTRODUCTION

Cheering the Lone Runner

It will never work. It can never be done. It is impossible. It will never be accepted.

How often, throughout modern history, have those words been spoken? There are dozens of classic examples. Physicist and engineer Lord Kelvin, president of the British Royal Society, famously said back in the late 1800s that "heavier-than-air flying machines are impossible" and "x-rays will prove to be a hoax." Albert Einstein said in 1932 that he couldn't see nuclear energy ever being obtainable. Tunis Craven, in his role as commissioner of the U.S. Federal Communications Commission in 1961, spoke a few years prematurely when he dismissed the future prospect of communications satellites. "There is practically no chance communications space satellites will be used to provide better telephone, telegraph, television, or radio service inside the United States," pronounced Craven, only to be proven wrong when the satellite Syncom 3 transmitted television signals from Japan to the United States, giving Americans live foreign coverage of the 1964 Summer Olympics. Many theoretical physicists

during the late 1960s and '70s said nuclear magnetic resonance technology, first discovered in the 1930s, could not be adapted to detect cancers and other diseases in the human body. A New York physician named Raymond Damadian ignored the naysayers and built his own body scanner. In 1977 he successfully performed the first full-body magnetic resonance imaging (MRI) exam on a human. Receiving an award from the Massachusetts Institute of Technology in 2001, Damadian said criticism and skepticism come with the territory of invention and innovation: "The bolder the initiative, the harsher the criticism."[1] A gracious response, but I rather like the comment by *Time* magazine writer Lev Grossman, "There's nothing like the passage of time to make the world's smartest people look like complete idiots."[2]

In the area of energy technology and systems, it's arguable that no one has been doubted, underestimated, or challenged more than Serbian-American engineer Nikola Tesla (1856–1943), and perhaps no innovator has proven so many people wrong over the past 100 years. His best-known invention was the alternating current (AC) induction motor, patented in 1888, which became crucial to the subsequent development of high-voltage AC power systems that could distribute electricity over long distances. Direct current (DC) systems of the day, by comparison, were limited because they produced electricity that had to be consumed within a couple of kilometers of where it was generated. Tesla appreciated early in his life the benefits of AC and the shortfalls of DC, and he first began formulating his AC motor designs as a student at the Austrian Polytechnic School in Graz. One day, after sharing his thoughts with a professor he greatly respected, the young Tesla, in his early 20s, was promptly rebuffed in front of his peers. "Mr. Tesla may accomplish great things," his professor quipped, "but he will never do this . . . It's a perpetual motion machine, an impossible idea."[3] Of course, what Tesla described had nothing to do with perpetual motion. Yet his professor, unable to grasp the concept, did not hesitate to lump it into the category reserved for loony inventions.

A few years later, while walking in a park late one afternoon with a friend, Tesla said a clear design for his motor shot into his head "like a flash of lightning." He found a stick and began drawing diagrams in the dirt. Six years later, he formally revealed the design to the American Institute of Electrical Engineers, though the battle to have it more widely accepted was just beginning.[4] As he forged on and turned his idea into a working prototype, he faced resistance from American inventor Thomas Edison, who saw all inventions around alternating current as a threat to the low-voltage, direct-current systems he was developing and from which he was collecting handsome royalties. "Fooling around with alternating current is just a waste of time," said Edison in 1889. "Nobody will use it, ever." To discourage its use, Edison declared high-voltage AC systems unsafe and lobbied the U.S. government to ban the technology on those grounds.[5] He drove the message home by funding a vicious public relations campaign that involved electrocuting dogs and other animals — including an elephant — with AC current. His campaign didn't work, of course, and AC power generation and transmission systems based on Tesla's designs eventually came to dominance around the world. It wasn't an impossible waste of time after all.

I first became fascinated with the life and work of Nikola Tesla 10 years ago while researching a story marking the 100th anniversary of Guglielmo Marconi's first transatlantic wireless communication. On December 12, 1901, the letter "S" was transmitted in Morse code from a wireless transmission station in Cornwall, United Kingdom, to Signal Hill in St. John's, a city in the Canadian province of Newfoundland and Labrador. The 3,500-kilometer transmission across the Atlantic Ocean was hailed as a great moment in science and eventually led to Marconi being branded as "The Father of Radio." It's a nice story, except for the fact that Tesla was the true father of radio. Tesla filed his first radio patents in 1896, five years before Marconi, and when Marconi did file to the U.S. patent office, it initially rejected his application for being too similar to those submitted by Tesla. It was only when the U.S. Supreme Court ruled on the patent issue nearly 50 years later,

in 1943 just a few months after Tesla's death, that the matter was settled for good: Tesla invented radio.

The more I dug into the life of Tesla, the more I realized how much his inventions and vision influenced the 20th century and continue to do so in our current century. In 1898 he demonstrated a remote-controlled robotic boat that heralded the beginning of remote-controlled electronics and multichannel broadcasting. Tesla called it "teleautomation" and referred to his boat as "the first of a race of robots — mechanical men which will do the laborious work of the human race." Learning this gave new meaning to the remote-controlled, battery-powered Spiderman helicopter I fly with my kids in the basement, though the larger influence is obvious — everything from the Mars Rover to unmanned drone planes to cruise missiles.[6] To those watching the demonstration in 1898, Tesla's invention seemed powered by pure magic. "Skeptics had him pull the lid to prove there wasn't a midget operating inside," according to documentarian Robert Uth.[7] But there was little financial interest in the idea at the time, and Tesla explained such reluctance to invest — and even hostility to the concept — when he requested development funds from American millionaire John Jacob Astor IV. "It is for a reason that I am often and viciously attacked," he wrote in a letter to Astor, "because my intentions threaten a number of established industries."[8] Astor, who went down with the *Titanic* in 1912 at the age of 47, would only live long enough to get a taste of how Tesla's robot race would evolve.

There seems to be no end to Tesla's accomplishments. He is credited in hindsight for perfecting neon and fluorescent lighting, for the earliest work in wireless power transmission, for taking the world's first x-ray photographs, and for proposing the basic principles of radar technology two decades before its "official" invention.[9] Even his ability to create "lightning balls" in the laboratory has inspired research into plasma physics and nuclear fusion. An inventor and visionary, Tesla was also an environmentalist at heart who understood the long-term implications of burning fossil fuels, the supply of which would eventually

run out. Non-renewable resources such as coal and oil should be conserved, he argued, and solar energy — either acquired directly or indirectly by capturing energy in the wind — should be fully exploited. At age 75, he published designs of two renewable energy extraction methods in the December 1931 issue of *Everyday Science and Mechanics*. One was an early design of a geothermal power plant of the sort built today to extract heat from deep underground for clean electricity production. The second was a way to generate electricity from the temperature differential in ocean waters.

Essentially, a heat exchanger would extract heat out of the warmer upper ocean layers and create steam from a working fluid with a low boiling temperature, such as ammonia. The steam would drive a turbine that generates electricity. Cold water from deeper layers would then be used to condense the ammonia back into fluid, at which point the cycle would be repeated. It seemed an unpractical and somewhat wonky concept at the time, and Tesla himself struggled to make it efficient enough to be worthwhile. But the idea, today called ocean thermal energy conversion (OTEC), lives on. Military contactor Lockheed Martin has been working away on the technology since the 1970s and is now constructing a 10-megawatt OTEC pilot plant off the coast of Hawaii that could be in operation by 2013. It would generate enough power for 10,000 homes. "I dream of thousands of floating OTEC ships roaming the seas of the world, providing an inexhaustible supply of clean energy and fuel and water for all people of the world," explained an enthusiastic Ted Johnson, director of alternative energy development at Lockheed.[10] It's a comment Tesla might have made 100 years ago.

It's no wonder Tesla is regarded today as one of the greatest inventors and thinkers of the 20th century. But the label only took hold many years after his death. And it didn't come without a fight. In many respects, he was an underdog his entire career, despite his lifelong creativity and brilliance. Born July 10, 1856, in the Croatian village of Smiljan, the young Nikola was a sickly and quirky child who developed many phobias and obsessions

that were carried into adulthood. When he walked, he couldn't help but count his steps. When served meals, he was compelled to calculate in his mind the cubic contents of cups and bowls. He also had a problem touching people's hair and, generally, had a phobia of germs. The sight of earrings dangling from a woman's earlobes disgusted him, especially if they were pearls. This developed much later in life into other obsessive-compulsive behaviors, most notably a fixation on the number three. He often walked around the block three times before entering a building, or he would demand that certain items be sent to him in threes. Such eccentric behavior may explain why Tesla never married or engaged in romantic relationships during his life. Poor and feeble in his final years, his only known "love" was a white pigeon that would regularly visit his apartment. It was during these final years that Tesla also spoke openly about a future that most people could not imagine, let alone believe.

According to the documentarian Uth, "Newspaper reporters, looking for a laugh, would attend to listen to the crazy old man's outlandish predictions of wireless telephones, communication with other life forms in the cosmos, beam weapons that could shoot down airplanes and missiles, and many more science fiction concepts that are now becoming reality." Instead of being hailed as a genius and brilliant inventor, Tesla was increasingly thought of as a "mad scientist" in the minds of the general public and in popular culture. In 1941, the first Superman cartoon movies, for example, had the Man of Steel fighting a mad scientist named Tesla and his city-destroying "electrothanasia ray," representing Tesla's real-life work on a particle beam that could be used as a weapon of war. Perhaps Tesla seeded such perceptions of madness as early as 1901 when he claimed he had been in communication with Mars, implying some sort of back-and-forth chatter with extraterrestrials. Conspiracy theorists suggest such communications informed Tesla's reported early awareness of rising carbon dioxide levels in Earth's atmosphere and how it was causing global warming.[11] Needless to say, Tesla was just as often a target of ridicule as he was of praise. "He was a really

weird dude," Amory Lovins, chief scientist and co-founder of the Rocky Mountain Institute in Colorado, told me one day while I was researching this book. "He probably would have been in a mental institution today."

One wonders how many brilliant minds are undiscovered, locked away or medicated, and to what extent our aversion to "weird dudes" puts a cap on innovation. Another question is whether Tesla's strange ways contributed in a way to his genius, or whether it was his genius that led to his strange ways. I keep coming back to a line in the Francis Ford Coppola movie *Rumble Fish*, in which Dennis Hopper's character answers a not-so-simple question from his son Rusty James (Matt Dillon): was mom crazy? "Every now and then a person comes along that has a different view of the world than does the usual person," says Hopper's character. "It doesn't make them crazy. I mean, an acute perception, man — that doesn't make you crazy. However, sometimes it can drive you crazy." What we know is that Tesla's acute perception of the world around him informed a kind of thinking that most others could not easily grasp or appreciate. To be misunderstood can make one appear mad in the eyes of others. But being misunderstood, over time, is just as likely to drive one mad.

A voracious reader, a lover of poetry, and a man blessed with a photographic memory, Tesla somehow managed to balance his eccentric ways with social acceptance for most of his life. Mark Twain enjoyed hanging around him, and the two became close friends. The social elite of New York City, where Tesla lived, loved to rub elbows with the strange-but-fascinating inventor who had a lovely accent and slim build. But, ultimately, the Serbian-American engineer was a loner both in how he lived and in his head. He kept ideas locked up inside his mind and, to the frustration of many, did not collaborate well with other engineers and scientists. His ideas and achievements were his and his alone, as was his struggle to have those innovations accepted by society. This isolation, and the fact that he has proven so many skeptics wrong over the years, has endeared Tesla to many inventors and

entrepreneurs who identify with his struggle. "The example set by Tesla has always been particularly inspiring to the lone runner," wrote Margaret Cheney, author of *Tesla: Man Out of Time*.

Indeed, one of the inventor's 21st century namesakes is electric car maker Tesla Motors, which relies on a modern version of Nikola Tesla's "polyphase" AC motor design. The company's Tesla Roadster is a $109,000 battery-powered sports car with a 230-mile range and acceleration that can leave a Porsche in its dust. Its early critics considered it a flash in the pan — a shiny, fast toy for the uber-rich that won't last beyond its initial buzz. Many still view the company this way. As a pioneer of electric cars, and the first automaker born out of Silicon Valley, Tesla Motors is very much a lone runner that's used to being told "it can never been done" and "it will never be accepted." Yet the company, like the inventor, has not been discouraged by the naysayers. This is made clear on its corporate website: "The critics said it couldn't be done, yet we are here, taking nothing for granted. We challenge custom and question tradition. Our drivers benefit from it." Since Tesla Motors emerged on the scene, most major automakers, including those that declared electric cars a short-lived fad, have announced plans for their own all-electric or plug-in hybrid vehicles. The global transition to electrified transportation is building momentum, and it's now viewed by many as almost inevitable.

This book explores some of the other "lone runners" out there who I have identified during my six years as an energy reporter and clean technology columnist for the *Toronto Star*, Canada's largest daily newspaper, and as a frequent contributor to MIT's *Technology Review*. I titled it *Mad Like Tesla* because, in my observation, the companies and individuals profiled here have reason to identify with Nikola Tesla, the man. They are considered — or have been considered — crazy because of the perceived impossibility or unacceptability of what they're attempting to do, and yet they forge ahead in an inhospitable marketplace driven largely by a desire to do right and a conviction that they are right. In this sense, they are mad like Tesla — not because women's

earrings make them vomit or they claim to have communicated with Martians, but because of how easily society dismisses their potentially game-changing efforts and because of the barriers they face along their journeys. The barriers are many: scientific groupthink, bad timing, entrenched corporate interests, misplaced public fear, gaps in available technology, high cost, resource scarcity, personality clashes, lack of financing, resistance to change, complacency, competitive rivalry, misguided policy, lack of vision, and general ignorance — to name just a few. Many of these barriers will be discussed in the chapters that follow. "It's a surprise some people ever start," industry watcher Rick Whittaker once told me. He's the chief technology and investment officer at Sustainable Development Technology Canada (SDTC), a federal granting agency created to support clean technology demonstration projects. Hundreds of funding applications cross Whittaker's desk each year. Many deserving ideas slip through the cracks. Those persistent or lucky enough to get funding are only at the beginning of a very long road. The casualty rate is high.

So why did I write this book? Humanity is on an unsustainable path, and changing course will require a dramatic rethink of how we obtain and use energy. We need to be more open minded. We need to take more chances. The individuals and companies profiled in the chapters that follow play a crucial role in our energy future, even if they fail. That's because, like Tesla, they still succeed by leading, by taking risks, by pursuing great leaps, and by keeping open minds when others remain so closed. They stand in contrast to monolithic corporations with disciplined management cultures and an aversion to disruptive technology. As U.S. inventor Dean Kamen, creator of the Segway scooter, once said, "Good management tries to eliminate surprise, therefore good management eliminates innovation." Fact is we need the lone runner, be it a passionate individual or an aggressive startup that doesn't stop at "no" and isn't satisfied with taking baby steps. But who are these people? What drives them? What goes through their minds? Though we see the sensational headlines that briefly

shine a light on their unusual technologies — the so-called 15 minutes of fame — too often these innovators' stories and their contributions to the world fade into the background. The real learning comes out of the journey behind the headline.

But let's be clear: the nimble and creative David isn't guaranteed to come up with a better concept or technology than a slow and stifled Goliath. Even Tesla had his duds, as author Judy Wearing illustrates so well in her book, *Edison's Concrete Piano*. Tesla's "earthquake machine" wasn't of much value, and his cosmic theories aimed at refuting Einstein's theory of relativity were well off the mark. I also don't want to suggest that simply proving a ground-breaking idea both technologically possible and superior is all it takes to earn rapid acceptance, as writer Vaclav Smil discusses in his book *Energy Myths and Realities*. "Wishful thinking, pioneering enthusiasm, and belief in the efficacy of seemingly superior solutions are not enough to change the fundamental nature of gradually unfolding energy transitions, be they shifts to new fuels, to new modes of electricity generation, or to new prime movers," wrote Smil. His point is well taken. Pieces of an energy system aren't iPod-like gadgets with a six-month shelf life. They are part of a massive infrastructure that has come together over several decades at a cost of hundreds of billions of dollars. Meaningful change on a global scale will take many decades more, so we'll need to temper passion with patience.

Energy expert David Fridley, a scientist at Lawrence Berkeley National Laboratory in California, writes that too many of us underestimate the grueling path to commercialization, even for truly breakthrough energy technologies. "Processes need to be perfected and optimized, patents developed, demonstration tests performed, pilot plants built and evaluated, environmental impacts assessed, and engineering, design, siting, financing, economic and other studies are undertaken. In other words, technologies that are proved feasible on the bench-top today will likely have little impact until the 2030s."[12] It's also not a sure thing that a new game-changing technology can be scaled up enough

to have the kind of global impact that's expected. Maybe it relies on a rare-earth metal that's in very short supply or is limited by geography or needs to consume huge volumes of fresh water at a time when water is increasingly scarce. These variables must be carefully weighed and considered.

With all of that duly noted, in Chapter 1 you'll meet Michel Laberge, a Quebec-born engineer who worked for a high-tech commercial printing company until he turned 40 and had what he considers a mid-life crisis. Most men would buy a Porsche and start dyeing their graying hair. Not Laberge. He decided to dedicate his life to building a nuclear fusion power reactor on the cheap. His Vancouver-based company, General Fusion, is trying to do with tens of millions of dollars what government-led projects in Europe and North America are struggling to do with tens of billions. He understood the odds were against him when he started, but ask him today and he'll tell you it's a 50–50 bet and the odds are getting better every day. If he pulls it off, clean and cheap nuclear power without the toxic waste just might be a reality in our lifetime.

Chapter 2 introduces you to a California company that wants to go where no power plant has gone before — space. Solar photovoltaic technology has been used for decades to power satellites, but Gary Spirnak wants to take an idea first proposed by science fiction writer Isaac Asimov in 1941 and — in the words of next-gen *Star Trek* captain Jean-Luc Picard — make it so. A square kilometer solar collector would be launched into orbit about 36,000 kilometers above the surface of the Earth, clear of clouds and facing the sun 24 hours a day. The energy collected would be beamed by microwave down to a massive receiving station in the middle of a desert, converted into electricity, and put on the power grid. Sounds crazy, I'll admit. Spirnak, founder of Solaren Corporation, admits it's an enormous endeavor that invites ridicule, but, as an engineer and veteran of the U.S. space industry, he is convinced it can be done with current technology and that the electricity produced will be competitively priced.