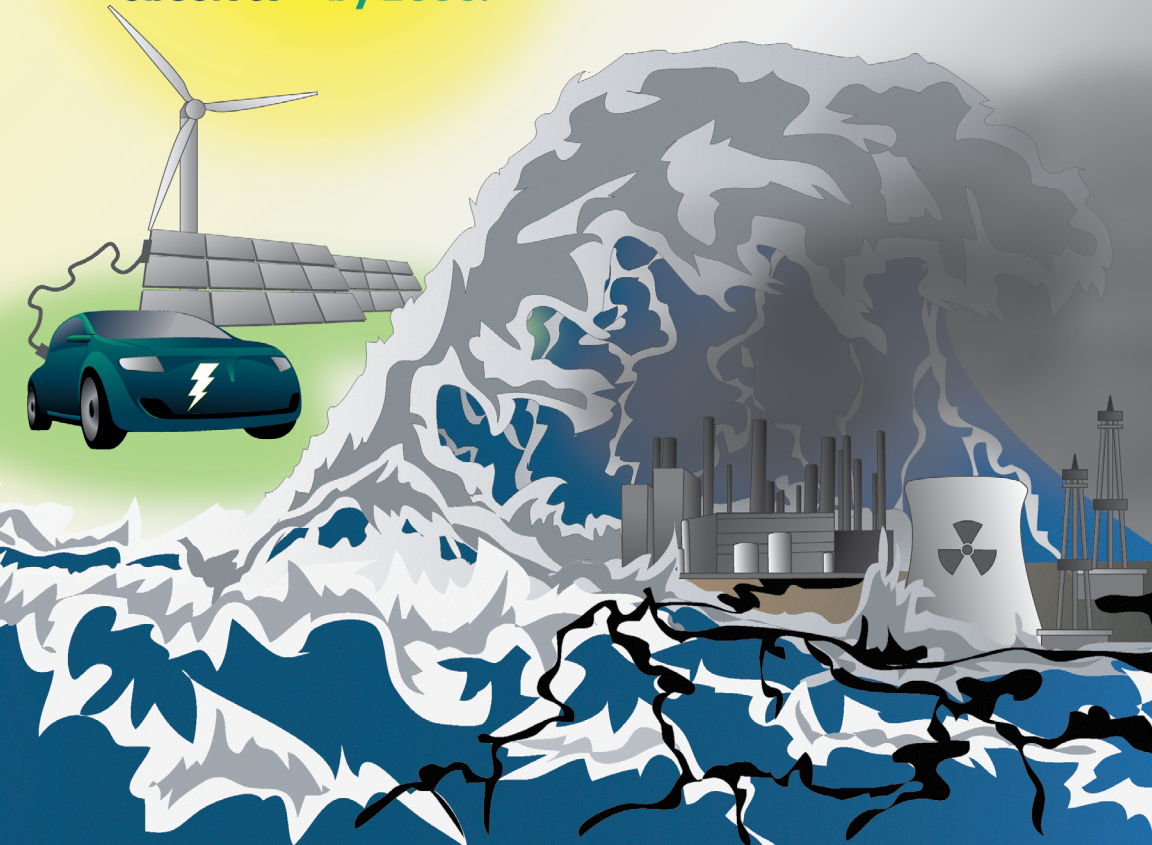


CLEAN DISRUPTION

OF ENERGY AND TRANSPORTATION

Tony Seba

How Silicon Valley
is making oil, nuclear,
natural gas, coal,
electric utilities and
conventional cars
obsolete - by 2030.



Clean Disruption of Energy and Transportation

How Silicon Valley Will Make Oil, Nuclear,
Natural Gas, Coal, Electric Utilities and
Conventional Cars Obsolete by 2030

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Introduction:

Energy and the Stone Age

*“An age is called Dark not because the light fails to shine,
but because people refuse to see it.”*

James Michener

*“If the rate of change on the outside is greater than
the rate of change on the inside, the end is near.”*

*Jack Welch,
former CEO, General Electric*

“It always seems impossible until it’s done.”

Nelson Mandela

Introduction: Energy and the Stone Age

The Stone Age did not end because humankind ran out of stones. It ended because rocks were disrupted by a superior technology: bronze. Stones didn't just disappear. They just became obsolete for tool-making purposes in the Bronze Age.

The horse and carriage era did not end because we ran out of horses. It ended because horse transportation was disrupted by a superior technology, the internal combustion engine, and a new, disruptive 20th century business model. Horses didn't just disappear. They became obsolete for the purposes of mass transportation.

The age of centralized, command-and-control, extraction-resource-based energy sources (oil, gas, coal and nuclear) will not end because we run out of petroleum, natural gas, coal, or uranium. It will end because these energy sources, the business models they employ, and the products that sustain them will be disrupted by superior technologies, product architectures, and business models. Compelling new technologies such as solar, wind, electric vehicles, and autonomous (self-driving) cars will disrupt and sweep away the energy industry as we know it.

The same Silicon Valley ecosystem that created bit-based technologies that have disrupted atom-based industries is now creating bit- and electron-based technologies that will disrupt atom-based energy industries.

Clean Disruption of Energy and Transportation

The industrial era of energy and transportation is giving way to an information technology and knowledge-based energy and transportation era. The combination of bit-based and electron-based technologies will put an end to conventional atom-based energy and transportation industries. The disruption will be a clean one and have the following characteristics:

1. Technology-based disruption.

The clean disruption is about digital (bit) and clean energy (electron) technologies disrupting resource-based (atom-based) industries. Clean energy (solar and wind) is free. Clean transportation is electric and uses clean energy derived from the sun and wind. The key to the disruption of energy lies in the exponential cost and performance improvement of technologies that convert, manage, store, and share clean energy.

2. Flipping the architecture of energy.

Just as the Internet and the cell phone turned the architecture of information upside-down, the clean disruption will create an energy architecture that is different from the one we know today. The new energy architecture will be distributed, mobile,

intelligent, and participatory. It will overturn the existing energy architecture, which is centralized, command-and-control oriented, secretive, and extractive.

3. Abundant, cheap, and participatory energy.

The clean disruption will be about abundant, cheap, and participatory energy. The existing energy business model is based on scarcity, depletion, and command-and-control monopolies. The clean disruption is similar to the information technology revolution that overturned the old publishing and information model and made information abundant, participatory, and essentially free.

4. Clean disruption is inevitable.

The clean disruption of energy and transportation is inevitable when you consider the exponential cost improvement of disrupting technologies; the creation of new business models; the democratization of generation, finance, and access; and the exponential market growth.

5. Clean disruption will be swift.

It will be over by 2030. Maybe before.

Oil, natural gas (methane), coal, and uranium will simply become obsolete for the purposes of generating significant amounts of electricity and powering the automobile. These energy sources will still have uses. For example, uranium will be used to make nuclear weapons and natural gas will be used for cooking and producing fertilizer. Obsolescence and clean disruption will not put an end to incumbent industries. We still have vinyl records, sailboats and jukeboxes. These niche market products will survive, but energy and transportation will not be the multi-trillion dollar energy heavyweights that they are today.

In twenty years we'll wonder how we put up with the horrendous consequences of the incumbent, conventional, \$8 trillion-a-year energy industry. If Nikola Tesla and Thomas Alva Edison rose from the dead, they would recognize the industry that they helped build a century ago — and they would be disappointed at how little it has changed. Today's versions of Tesla and Edison are creating technologies, products, and business models that will dismantle the extractive, centralized, dirty-energy age in which we live.

The first wave of energy disruption has already begun with distributed solar and wind generation. It won't be long before the next wave crashes over the remains of the first one.

Transportation is a \$4 trillion industry globally. The transportation industry is inextricably linked with energy. As this book explains, the internal combustion engine automobile will soon be disrupted, an event which will, in turn, send disruptive shockwaves through the oil industry.

The first wave of disruption of the century-old automotive industry is well underway with electric vehicles. The second disruptive wave, the self-driving car, will hit before the first

wave is finished crashing. Transportation will never be the same again.

This book is about how a new technology-based infrastructure and a set of products and services governed by the economics that have made Silicon Valley a source of market disruption over the last generation will disrupt energy industries that have barely evolved over the past hundred years.

A Classic Silicon Valley Technology Disruption

Companies such as Apple, Google, Intel, Cisco, Facebook, Twitter, and eBay are governed by information economics. These technology companies grew fast and strong because of the economics of increasing returns.

Resource-based energy companies are based on the economics of decreasing returns. Silicon Valley is about abundance, business model innovation, participatory culture, and democratizing power. Resource energy is about scarcity, extractive thinking, hierarchical culture and centralized power.

To explain the power of clean disruption, it helps to look at a recent industry that was disrupted by Silicon Valley — film photography.

Zero Marginal Cost and Waves of Disruption

The age of film photography did not end because we ran out of film. We did not run out of any of the components needed to make film or film cameras. Film photography was destroyed by rapid improvements in digital imaging and information technologies, disruptive business models, and a participatory culture with which industry leaders Kodak and Fujifilm simply could not compete.

Twentieth-century photography leader Kodak's business model was to make money every single time anyone, anywhere clicked his or her camera. Every click was a cash transaction for Kodak. Every click involved burning film (cash for Kodak). The film had to be processed with special paper (cash for Kodak.) The paper needed a printer developed especially for after-market photo stores (cash for Kodak). Want to double size it and get two copies of each photo? Cash for Kodak.

Digital cameras changed the equation. Once a photographer had a digital camera the marginal cost of taking additional pictures dropped essentially to zero. The photographer did not have to pay for film, film processing, or printing photographs. Just load the files on your computer and enjoy. Erase your camera USB drive, take as many pictures as you like, load the files on your computer and enjoy. Repeat forever.

The energy and transportation industries have a business model similar to Kodak's. Every time you flip a switch to turn on a light, more cash is paid to the utility. Every flip of the switch involves burning coal, oil, gas, or uranium and, again more cash for resource-based energy suppliers. Every time you press the gas pedal in your car, you give cash to the oil industry. Substituting natural gas or ethanol for gasoline doesn't change the business model. Every time you press the gas pedal you still burn fuel and give cash to the energy industry.

Solar and wind power change the energy equation in the same way that digital cameras changed the film camera equation. After you build a solar rooftop installation, the marginal cost of each additional unit of energy drops essentially to zero because the sun and the wind are free. Flipping a light switch burns nothing and means zero cash for the utility.

This applies not just to rooftop solar. Utility scale solar and wind also change the equation in competitive wholesale electricity markets. Solar and wind have a marginal cost of zero. Chapter 3 explains how zero marginal costs are already disrupting utilities that rely on coal, nuclear, gas, and oil for energy generation.

Kodak and its film photography supply chain did try to compete with digital photography (see Figure I-1). For instance, Kodak developed technologies to speed up development time from days to hours. But what was disruptive about digital photography was not just the technology itself, but the business model innovations that came with it. Under these models, the marginal cost of a new photo dropped to zero. That was something Kodak could not compete with.



Figure I.1 – Obsolete one-hour film developing store. (Photo: Tony Seba)

The story of how digital photography disrupted traditional photography didn't end with Kodak. The next disruption wave came in the form of San Francisco-based Flickr, which made it easy to publish and share photos online. Again the cost of uploading and storing each picture dropped to zero.

Companies like Picasa made it easy to store photos on your computer and online. Again, the cost of each additional picture was nil.

Next came the social media disruption wave. Facebook became the largest photo publisher in the world.

Not much later, the smartphone disruption wave swooped in. Smartphone cameras were just as good as standalone cameras or at least good enough for everyday photo taking. You could take photos, process them, and instantly publish them online without leaving your smartphone. Instagram, a startup company in San Francisco with a dozen employees, simplified this process and within a few months became the fastest growing photo publisher in the world. Facebook acquired Instagram for \$1 billion before Instagram could become an existential threat to the social network.

What happened in photography and what is happening in many other industries is what I call “waves of disruption” or “disruptive waves.” These waves used to happen every century or maybe every generation. The computer industry sped up disruption waves so they occur every decade or so (see Figure I.2).

Now we live in an era of permanent disruption. Just as soon as the disrupting companies start celebrating their triumph over the former incumbents, they become the targets of the next wave of disruptors.

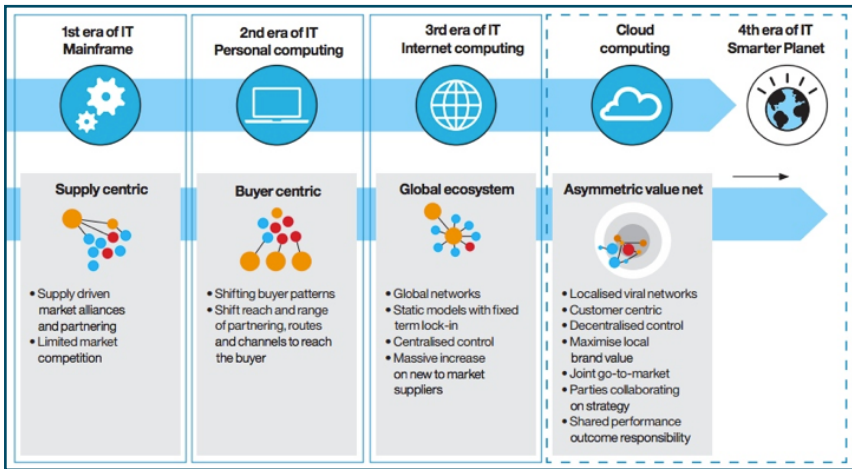


Figure I.2—Disruptive waves in information technology. (Source: IBM)

As soon as Sony started celebrating the triumph of its digital cameras over Kodak and Fuji, it was commoditized by web photo companies like Flickr. Flickr, meanwhile, was acquired by Yahoo!, and while the bottles of bubbly were being imbibed by Flickr employees, the Flickr photo site was disrupted by social media hubs like Facebook. Facebook, in turn, was threatened with disruption by Instagram. Now Instagram and Facebook are being

threatened by another fast-growing wave led by SnapChat.

The disruption of energy and transportation as we know it today is being led by three main sets of technology-based products:

1. Solar
2. Electric vehicles
3. Autonomous (self-driving) cars

Solar is on its way to disrupting all forms of conventional energy. Solar is already cheaper than nuclear. It's already cheaper than retail electricity in hundreds of markets around the world, from Berlin to Seville to Palo Alto. In some markets solar has already pushed wholesale electricity prices down by as much as 40 percent.

Solar photovoltaic (PV) companies have decreased their costs by a factor of 154, a classic technology cost curve. Technology companies have an unparalleled record of lowering costs exponentially while increasing quality exponentially. The same economics that governed digital cameras, disk drives, microprocessors, routers, and mobile phones now govern solar PV technology development.

The electric vehicle is already better, faster, and safer than the internal combustion engine (gasoline) vehicle. Electric vehicles (EVs) are also cheaper to operate and maintain. An electric vehicle is still more expensive to purchase upfront, mainly due to battery costs. However, like other technology products, the technology cost curve of EVs points to a disruption soon; innovative business models will only accelerate the transition from gasoline vehicles to electric vehicles.

Internal combustion engine car companies will have their Kodak moment sooner than they think. By 2025, gasoline engine cars will be unable to compete with electric vehicles.

The autonomous (self-driving) vehicle will soon be better, faster, cheaper, and safer than vehicles driven by human drivers. The disruptive wave brought about by self-driving cars will wipe the last vestiges of the gasoline car and oil industries.

Technology Convergence and the Clean Disruption

In the clean energy field, the disruptors (solar, electric vehicles, and autonomous cars) complement and accelerate one another's adoption. For this reason, the disruption of energy and transportation as we know them today will be a dynamic one.

Think of the cell phone, the personal computer, and the Internet. They started out as different sets of products serving different markets, but their symbiosis complemented and accelerated one another's adoption in the marketplace. Cell phone, computer, and Internet router providers all benefited from the increased investment and R&D in smaller, more powerful, modular energy-efficient microprocessors, graphics processors, data

storage, and connectivity. In the end these formerly disparate industries converged. Together they formed a massive mobile computing infrastructure. This infrastructure encompasses everything from cell phones, smart phones, tablet computers and personal computers to data centers that host cloud-computing services.

These technologies have disrupted century-old industries while improving the lives of billions of people around the world.

Disruption comes in waves and we're still seeing disruption within the different classes of computers. Sales of personal computers are down and sales of mobile Internet platforms like the smartphone and tablets are up. Transitions in technology markets can be swift. It took twelve years to reach 50 million laptops, seven years to reach 50 million smartphones, but only two years to reach 50 million tablets.

Microsoft's Windows PC is out while Apple iOS iPhones and Google Android smartphones are in. Apple's iPad tablet is in and everyone else is still trying to catch up with Apple. The percentage of YouTube traffic that comes from mobile Internet went from 6 percent in 2011 to 25 percent in 2012 to 40 percent in 2013.

Similarly solar, the electric vehicle, and the autonomous vehicle started out as different sets of products and markets, but their symbiosis will complement and accelerate one another's technological development and adoption in the marketplace.

Increasing investments in electricity storage technologies in the automotive industry have led to more innovation and a subsequent drop in the cost of batteries like Lithium-Ion. As Li-on batteries become cheaper, they can increasingly be used — and economically be used — for solar and wind energy storage. The increased demand from solar and wind increases the scale of existing Li-on providers, which in turn pushes down the cost of EVs, solar, and wind.

The increasing demand for electric vehicles and solar will attract even more investment in these technologies. Innovative companies that can invent new ways to push costs down and push quality up will thrive. This virtuous cycle of increasing demand, increasing investment, and increasing innovation will dramatically lower costs; it will exponentially improve the quality benefits to both the clean energy and clean transportation industries; it will also lead to a convergence in which batteries can be used for transportation and for grid storage. Electric vehicles can be charged at work and become a source as well as a user of energy for the home. The result will be a swift transition from liquid-energy transportation to electric transportation.

The self-driving car will benefit from improvements in technologies such as artificial intelligence, sensors, graphics processing, robotics, broadband wireless communications, advanced materials, 3D visualization, Lidar, and 3D printing. These technologies will also benefit solar, wind, and electric vehicles.

Today, the self-driving Google car uses advances in Lidar 3D visualization technology (see Chapter 5). Lidar can also be used to make high-resolution maps for use in forestry, archeology, seismology, and other fields. For instance, the National Oceanic and Atmospheric Administration (NOAA) uses Lidar to collect data and develop 3D shoreline mapping tools. These tools will accurately map and project flooding and storm surges on the coasts of the United States.

Cities everywhere, from Cambridge, Massachusetts to San Diego, California use Lidar to develop “birds-eye view” 3D maps for use in urban planning, architecture, and design. Imagine a 3D Google-Earth-like SimCity map with which you can zoom in to any building, look at buildings from different angles, and virtually design different versions of a new house, clinic, or park.

As it happens, Lidar data developed to protect coastal populations, track earthquake fault-lines, and help city planners with urban design can also be used to develop more accurate assessments of a region’s solar potential; Lidar data can even be used to design solar installations on the rooftops of buildings. A recent MIT study concluded that designing a solar installation with Lidar data maps resulted in a “higher prediction of solar PV yield and a 10.8-percent reduction in costs.” Lidar can also be used to measure the speed, angle, and intensity of the wind, data that managers can use to improve the planning and operation of wind power plants.

Lidar is an example of an exponentially improving technology that can be used in autonomous and electric vehicles, solar and wind. As the market for autonomous vehicles grows, demand for Lidar will increase, which will attract more research and development investment in Lidar. The combination of these factors will lead to lower costs for Lidar products, which will benefit not just the autonomous vehicle industry but also solar and wind.

Because the self-driving car is basically a mobile computer, it will also benefit from improvements in existing Silicon Valley computing and communications technologies: data storage, computers, operating systems and applications software, communications, and graphics accelerators.

“Electric vehicles are the natural platform for autonomous cars,” said Takeshi Mitamura, director of the Nissan Research Center – Silicon Valley, speaking from his office in Sunnyvale. Nissan has announced the launch of an autonomous car by 2020.

Participatory Energy, Business Model Innovation and Disruption

The clean disruption of energy and transportation is also about innovative business models, designing new products and services, dominating small markets, and growing exponentially until the incumbents become collateral damage.

This disruption is also about a whole new architecture of energy.

The Internet disrupted information, communications, and computing in large part due to its distributed architecture. Information technology shifted from a centralized, supplier-centric, hierarchical model to a distributed, customer-centric, participatory model. The way we produced, stored, distributed, and consumed information changed radically.

Distributed technologies, which were enabled by innovative, disruptive business models, in turn allowed new technologies to flourish, and these technologies in their turn caused a change in the culture of information. Information changed from a centralized to a participatory model. In the end, the shift from centralized to distributed information technologies changed everything about the industry; it even changed society at large. People don't want to just consume content; they want to create and share it. Companies that enable people to participate in the generation and dissemination of content have been amply rewarded. Witness the rise of Facebook, Twitter, and LinkedIn.

Energy will be no different.

Millions of routers were needed to build and underpin the Internet infrastructure. Today, solar panels and electric vehicles are needed to underpin the new energy infrastructure and transportation infrastructure. But make no mistake, solar and electric vehicles are also about a shift in the architecture of energy. This new energy architecture will change the way energy is produced, stored, distributed, and consumed. It will bring about new disruptive technologies and business models, and even a cultural shift in the way we think about energy.

The Participatory Energy Model

The information technology revolution pushed processing power and intelligence from the center to the edges. We went from the mainframe, to the minicomputer, to the personal computer, to the cell phone and tablet in less than three decades. The nodes are getting smaller, more connected and more intelligent. We're far from done with this transition. The trillion-sensor world is right around the corner.

The information technology revolution was not brought about only by the miniaturization of technologies. This was a transition from a supplier-centric, centralized information model to a user-centric, participatory information model.

Twenty-first century digital consumers have grown to feel empowered by distributed technologies built on the Internet and the smart mobile phone. Consumers who previously had access to one or two local newspapers now can get information from anywhere in the world. The local paper hasn't died but it's wounded and weak.

Following in the footsteps of information technology, the energy and transportation disruption is quickly moving towards a participatory energy model. We're headed toward a distributed architecture of energy production and usage made possible by software, sensors, artificial intelligence, robotics, smartphones, mobile Internet, big data, analytics, satellites, nanotechnology, electricity storage, materials science, and other exponentially improving technologies.

Solar is causing energy production to be pushed to the edges (customer site) from the center (large, centralized, hub-and-spoke power plants). The nodes are getting smaller, more modular, more connected, and more intelligent.

Welcome to the age of participatory energy, where every end user will be able to contribute to the financing, generation, storage, management, and trading of energy.

Thanks to the distributed nature of solar energy production and the open accessibility of information about energy, consumers can choose where they get their energy. The mobility and connectivity of electric vehicles will turn these vehicles into intelligent energy generation, storage, and management devices. Soon individuals will help decide which vendors provide energy and who will manage its efficient usage.

The Economics of Silicon Valley Technology: Increasing Returns

Distributed solar generation, the electric vehicle and the autonomous vehicle are information products. As such, they are governed by information economics and increasing returns. They are subject to Moore's Law as much as personal computers and tablets.

Increasing and Decreasing Returns: Technology vs. Extraction

Conventional energy resource economics is about decreasing returns. For this reason, conventional energy can't compete with technology industries based on increasing returns.

Take the new darling of conventional energy: hydraulic fracturing, also known as "fracking." To "frack" a single oil or gas well requires hundreds of trucks, millions of gallons of water, and tons of sand with hundreds of chemicals blasted through the ground. You also need thousands of miles of pipelines, massive factories to liquefy or compress the gas before it can be shipped or stored, massive ports with massive plants to decompress the gas and pipe it again to the power plant. Power generation can start only after all this Rube-Goldberg-device-like process is complete.

The returns on these wells start decreasing as soon as you start pumping the oil or gas. Despite all the talk of abundance and a "golden age of energy," fracked wells may deplete by 60 to 70 percent the first year alone.

The industry has started calling this depletion phenomenon the "Red Queen Syndrome" (after the Red Queen in *Through The Looking Glass*, who tells Alice "it takes all the running you can do just to stay in place"). Because of Red Queen Syndrome, you need to frack millions of new wells just to keep up with existing production. This is not just a "fracking" phenomenon. Production from traditional wells declines by half in about two years, after which the wells drip on for a few more years.

Extraction economics is about *decreasing returns*:

- The more you pump, the less each well produces.
- The more you pump, the less the neighboring well gets.
- The more you pump, the more each unit of energy will cost in the future.

Solar, electric vehicles and the clean disruption are about *increasing returns*.

Solar photovoltaic (PV) panels have a learning curve of 22 percent. PV production costs have dropped by 22 percent with every doubling of the infrastructure. The more demand there is in the market, the less your neighbor pays for her panels, and the more your neighbor benefits. Every time a solar power plant is built in Germany, Californians benefit from lower costs when the next solar power plant is built. Every solar panel sold in Australia cuts the cost of the next solar panel in South Africa. Lower costs benefit all new solar customers.

Every large solar power plant in the desert benefits not only the people who buy its power, but everyone who buys solar power in the future.

The higher the demand for solar PV, the lower the cost of solar for everyone, everywhere. Your neighbor benefits, the warehouse owner in Australia benefits, and future buyers of solar benefit from lower costs. All this enables more growth in the solar marketplace, which, because of the solar learning curve, further pushes down costs.

This mutually beneficial arrangement is the opposite of extraction industries like oil and gas. When China's demand for oil surged in the last decade, world prices for oil went up by a factor of ten. The higher the demand for oil in Beijing, the higher gasoline prices are in Palo Alto and Sydney.

This is not just a theoretical framework. Solar PV has improved its cost basis by more than five thousand times relative to oil since 1970 (see Chapter 7). By 2020, as the market for solar expands, solar will improve its cost basis relative to oil by twelve thousand times (see Chapter 7).

The economics of energy resource extraction, based on decreasing returns, just cannot compete with the economics of technology industries and its increasing returns.

The Red Queen Syndrome pushes the fossil fuel industry not just to extract more wells but

to dig deeper, use harsher chemicals, and create more wastelands. The fossil fuel industry has to do this just to stay in place. The BP Gulf Oil disaster and the monstrosity of the Alberta Oil Sands are not exceptions; they are the inevitable result of The Red Queen having to “run harder just to stay in place.”

Network Effects and the Clean Disruption of Energy and Transportation

Network effects explain why the value of a network increases exponentially even when adoption increases linearly. Network effects are the reason AT&T so thoroughly dominated telephony in the U.S. for a century; they explain why Microsoft Windows has generated so much cash for three decades and why Apple's iOS and Google's Android platforms have become so valuable. Network effects are a winner-take-all proposition; after a technology platform such as Windows, Android, or TCP/IP wins in a market with network effects, it's extremely difficult for others to compete in that market.

Network effects apply to the market for autonomous vehicles (AVs). As the value of the autonomous vehicles marketplace increases exponentially (not linearly), the market grows. The more autonomous cars on the road, the more each one benefits from other autonomous cars on the road (see Chapter 5). For this reason, the returns for companies that win in the autonomous vehicle market will grow with each additional AV in the market.

Network effects also mean that the market can grow at the exponential speed of Facebook, Apple iOS, and Google Android — not at the incremental rates of General Motors and British Petroleum.

Moore's Law and the Clean Disruption of Energy and Transportation

Electric Vehicles (EVs) are connected, mobile, information technology platforms.

The Tesla Model S does over-the-air software downloads to update or patch its operating system. This car has an embedded 3G connection and can also connect via WiFi. In this regard, the Tesla Model S is not very different from your smartphone or tablet computer. Clearly, the Tesla is not your father's Oldsmobile — and clearly your father's Olds manufacturer cannot compete with Tesla.

The electric vehicle is an information technology product. Like many information products, it benefits from Moore's Law (or a version thereof). Moore's Law states roughly that microprocessor technology improves at an annual rate of about 41 percent. According to the law, each subsequent year you can buy a computer that is 41 percent better (faster, smaller, more powerful) for the same dollar amount.

Compound that growth over many years and you get exponentially improving information products such as computers, smartphones, and tablets. This kind of technological improvement rate is the reason microprocessors are a thousand times more powerful than they

were twenty years ago and a million times more powerful than they were forty years ago. Exponential technology improvement rates explain why the Silicon Valley has produced industry-busting technologies and companies over the last few decades. You can't compete with exponentially improving products unless, of course, yours is also exponentially improving. If your competitor's rate of improvement is faster than yours, you're toast. It's just a matter of time before the bankruptcy lawyer is knocking at your door. Ask Kodak.

Hendy's Law is the imaging equivalent of Moore's Law. Discovered by Kodak's Barry Hendy in 1998, Hendy's Law states that the number of pixels per dollar doubles every 18 months. This translates to a compounded annual growth rate (CAGR) of 59 percent, which is even faster than Moore's Law. To be competitive in the digital imaging market, you have to match if not surpass this improvement rate.

Apple gets well-deserved credit for innovative and beautifully designed products, but open up one of those iPhones and you'll see exponentially improving technologies to go along with the wonderful design. The iPhone 5S has forty times the CPU performance of the original iPhone for a yearly improvement rate of 85 percent. The iPhone 5S also improved its graphics performance by 56 times for a yearly improvement rate of 96 percent!

Just to keep up with the iPhone, its competitors need to double the graphics performance every year while keeping the same cost!

If your competitor is riding a Moore's Law curve (or its equivalent) and you are not, your competitive offerings are doomed. It's just a matter of time before the disruption happens to your company. This applies inside as well as outside the industry. Ask Nokia and Blackberry.

Should Detroit auto executives lose sleep if Tesla's electric vehicles are riding a version of Moore's Law? How about several versions of Moore's Law, each corresponding to a different part of Tesla's technology offerings?

To keep up with advances in the electric vehicle, manufacturers of cars with internal combustion engines (ICEs) may pretend to ride a faster exponential curve, but they can't do it. Your father's Oldsmobile may improve at incremental rates (a few percentage points per year), but it can't improve at exponential rates. ICE vehicles are toast. Chapter 4 explores many reasons why the EV disruption wave is clearly coming.

Large, centralized, top-down, supplier-centric energy is on its way out. It is being replaced by modular, distributed, bottom-up, open, knowledge-based, consumer-centric energy. This disruption of the energy industry, coupled with the disruption of the automotive industry, will have a domino effect. Many industries will be disrupted: shipping, trucking, public transportation, car rentals, parking, and insurance.

City planning and land management will change dramatically. The ramifications are astonishing.

This is not just happening in Silicon Valley or in digital media. Every significant industry may be disrupted over the next ten to fifteen years.

The century-old energy and transportation industries are on the cusp of disruption. The transition has already started and the disruption will be swift. Conventional energy sources are already obsolete or soon to be obsolete. The business model that enables them cannot compete with the disruptive force of technologies like solar, electric vehicles, and self-driving cars. The innovative business models and participatory culture coming out of Silicon Valley will win the day.

What about the 100 Years of Oil (or Gas or Coal or Uranium)?

Do you recall the conversation in the 1990s about “peak paper” and whether the United States had enough paper to last a century? Me neither. The web did not disrupt the newspaper industry because we ran out of paper.

Do you recall the “peak vinyl” or “peak CD” crisis? Me neither. The web did not disrupt the music industry because we ran out of either.

The web was just a faster, cleaner, cheaper, more compelling way to produce, store, transmit, and consume content. The newspaper industry and music industry can't compete with the web. The web enabled disruptive products, services, and business models. It created a participatory culture that made the conventional newspaper and music industries obsolete.

The national conversation (if you can call it that) about energy in the media, political circles, and the energy industry is obsessed with whether we are at “peak oil” and whether there is enough natural gas (or nukes or coal) to last for thirty, one hundred, or four hundred years. This conversation misses the point entirely.

The cell phone did not disrupt the old landline telephone industry because we ran out of copper. Enough copper is underground to last one hundred years, but that is not a good reason to invest in landline telephony. Again, the cell phone industry disrupted landline telephony because mobile phones are a faster, cleaner, cheaper, more compelling way to communicate, and they can produce, store, transmit, and consume content.

Just substitute the words *oil*, *natural gas*, *coal* or your favorite conventional energy source for *paper*, *vinyl*, or *film* and you can peer into the future of energy.

The clean disruption of energy and transportation by Silicon Valley's exponentially improving technologies, new business models, and participatory culture is inevitable and it will be swift.

Energy and transportation as we know it today will be history by 2030.