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## Industry & Suppliers

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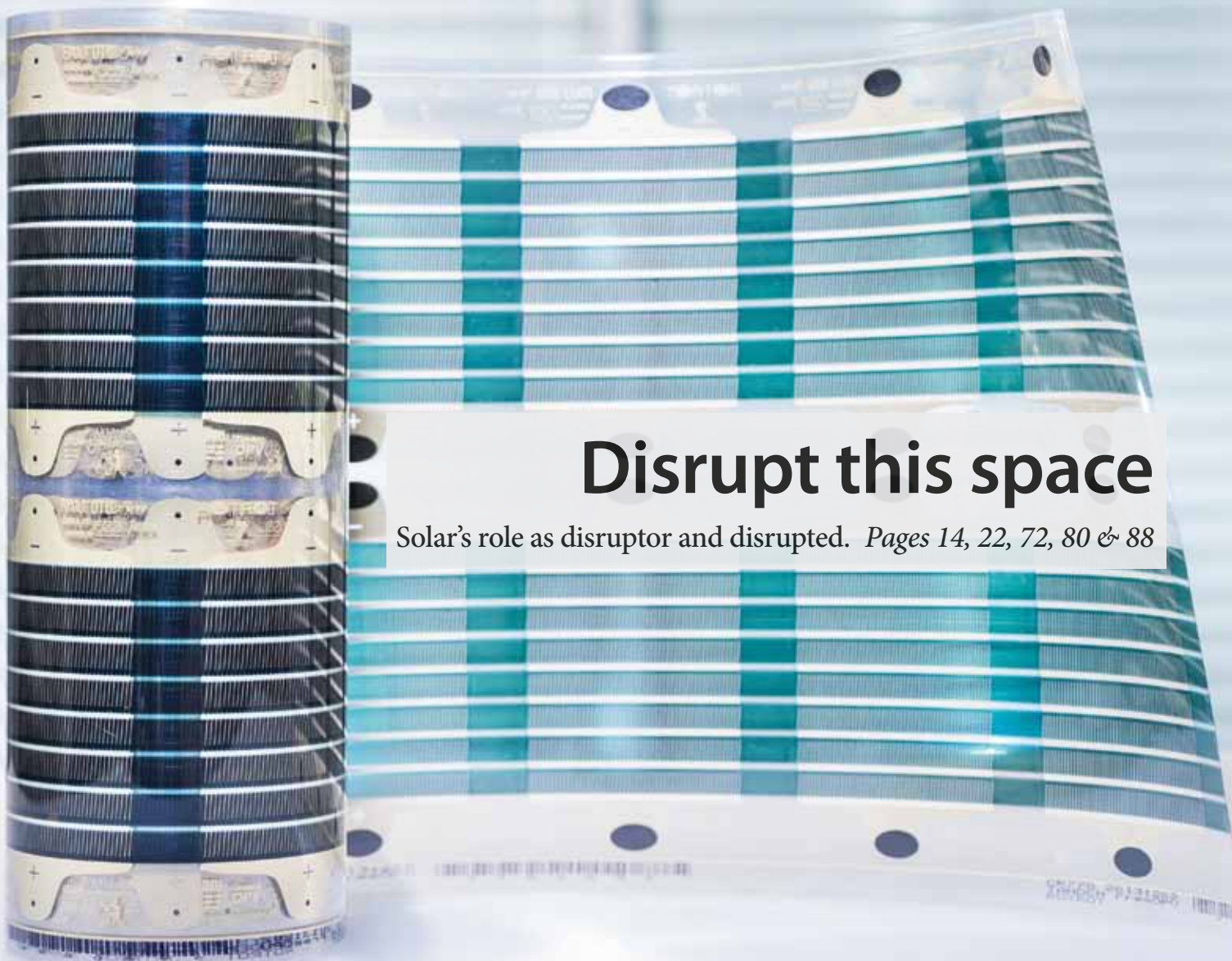


## Applications & Installations

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PHOTOVOLTAIC MARKETS & TECHNOLOGY



## Disrupt this space

Solar's role as disruptor and disrupted. *Pages 14, 22, 72, 80 & 88*



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Photo: KACO new energy

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Photo: FANUC America Corporation

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Photo: Tony Seba

Tony Seba is a lecturer in entrepreneurship at Stanford University, an entrepreneur with 20+ years of experience in high tech and clean technology companies, and the author of “Clean Disruption of Energy and Transportation,” “Solar Trillions” and “Winners Take All”. He holds an MBA from Stanford University Graduate School of Business and a B.Sc. in Computer Science and Engineering from the Massachusetts Institute of Technology.

## “It’s a one-two punch”

**Clean energy revolution:** Tony Seba is a lecturer in entrepreneurship, disruption and clean energy at Stanford University. He spoke to **pv magazine** about the themes in his new book, *Clean Disruption*, which looks at how solar, electric vehicles and other exponential technologies are leading to a clean, knowledge-based energy era.

**pv magazine:** *What role has photovoltaics played in the new energy revolution and in paving the way for the disruption of the existing energy architecture?*

**Tony Seba:** Solar PV is an essential component in the new energy revolution. The technology cost curve suggests that PV will become the world’s main source of energy well before 2030. The complementary technologies that will, together with PV, disrupt the whole energy industry are electric vehicles and self-driving cars.

PV technology is disruptive the way that the cell phone, digital cameras and the web were disruptive. There is really nothing that incumbents can do to prevent technology disruptions once they achieve critical mass.

**What characteristics of PV make it disruptive?**

Here are several characteristics of PV that make it disruptive: PV dematerializes energy. To understand this concept, think of how digital photography disrupted film photography. With digital imaging, photography went from atoms (film) to bits (digital), from something material that you had to manufacture for every single picture to something immaterial that is essentially free. Every time you flip a switch you burn fossil fuels or uranium. Every time you hit the car pedal you burn petroleum. Solar PV dematerializes energy by turning the sunshine photons directly into electrons and bits. You don’t burn anything to charge your computer. The same thing happens if you charge your electric vehicle with solar energy.

PV demonetizes energy. Each time you took a picture you burned film so Kodak made money. With digital photography the cost of taking each additional picture, storing it, sharing it

and viewing it is essentially zero. This is exactly what solar PV does to energy. Once you install a PV power plant the marginal cost of energy is essentially zero. Just like Kodak could not compete with a marginal cost of zero, there is no way on earth that energy companies can compete with PV’s marginal cost of zero. PV has increasing returns. PV is a technology whose costs have gone down by roughly 22% every two years for decades. Essentially the more PV is adopted the more everyone benefits from everyone else’s adoption of PV.

PV is scale-free. The same technology works to power a 1 W light bulb, a 1 kW house, a 1 MW business, a 10 MW factory, a 100 MW town, a 1 GW city and a 100 GW country. This is much like how information technology is scale-free: Our mobile phones, laptop computer and the most massive data centers work with similar modular technology building blocks.

It flips the architecture of energy. PV essentially flips the architecture of energy the way that the web flipped the architecture of publishing. In the old days publishing used to be done by a few companies who owned large centralized printers. They decided what would be published and pushed it down to the users. Now everyone with a Facebook, Twitter or LinkedIn account is a publisher. The same dynamics work for PV: Everyone can generate energy as well as information.

When you combine these disruptive characteristics of PV with the complementary disruptive characteristics of electric vehicles, it’s a one-two punch that conventional energy companies will not be able to survive.

**What are the biggest roadblocks currently standing in the way of a 100% renewable energy world?**



Photo: Dr. Klaus-Uwe Gerhardt/pixelio.de

Most job losses in the coal industry happened before solar started to play a role in the energy sector, says Seba.

I see two main roadblocks to a 100% clean – mainly solar but also wind – energy infrastructure: cost of capital and government regulation.

PV has become so cheap that the long-run cost of solar consists mainly of the cost of capital. In many markets banks are charging what are essentially credit card rates to finance solar installations. This is ridiculous since the data show that the default rate for solar is far below 1% – which puts it in the same risk category as mortgages. Fortunately, Wall Street has discovered that solar can provide a low-risk, high return cash flow. Over the last year or so we have seen mechanisms like solar securitization and yieldcos that have dramatically cut the cost of solar finance. This hasn't happened in every market yet, but like every technology adoption life cycle, these financial innovations will spread to every major market throughout the world.

This brings me to what I see as the major roadblock to a 100% clean energy world: governments. Policy makers block the growth of solar in many ways.

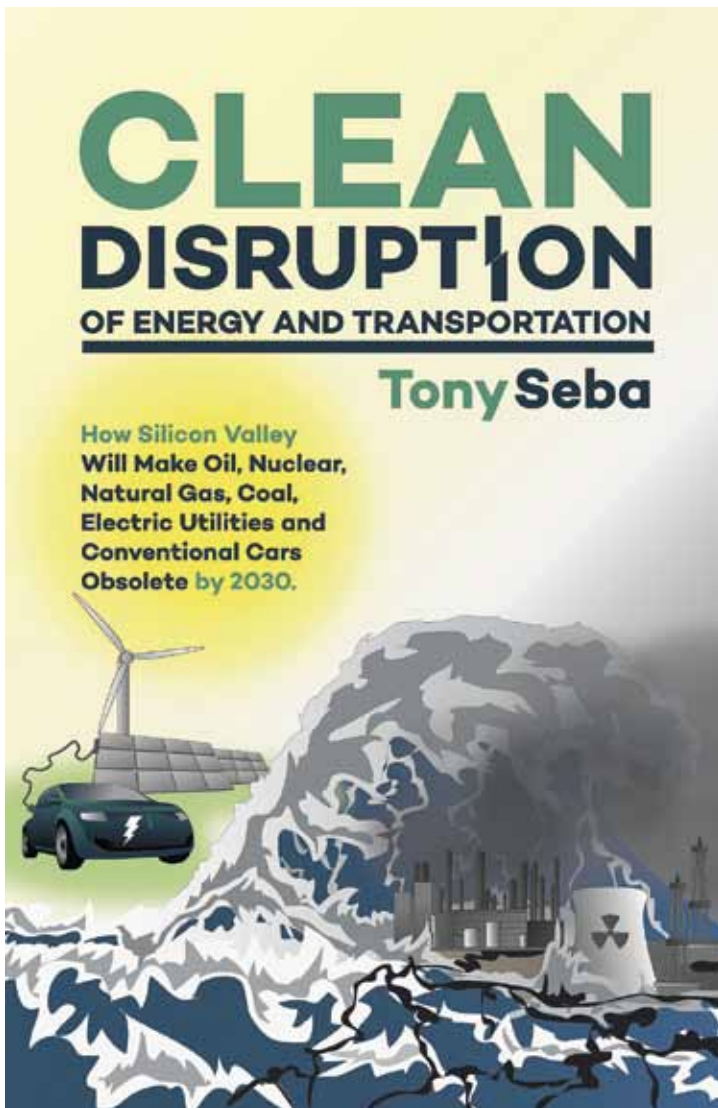
First, they subsidize and protect conventional energy industries. According to the International Monetary Fund (IMF), world governments spend \$2 trillion every year subsidizing fossil fuels. These subsidies hook whole populations on artificially cheaper sources of dirty energy. This prevents them from switching to solar and electric vehicles even as they become cheaper.

Second, governments also provide incumbents with corporate tax breaks that they don't make available to clean energy. For instance, in the United States, fossil fuel companies have raised nearly half a trillion dollars using a business structure called master limited partnerships (MLP). MLPs have the tax

advantages of a limited partnership, but its stock can be traded like corporate stock. Unlike typical "C" corporations, which have to pay corporate taxes, MLPs pay no corporate tax. This gives them a huge advantage. Their net earnings pass through to the shareholders as dividends. Fossil fuel companies can raise cheap money using MLPs but clean energy (solar and wind) projects cannot use them. Like I said before, solar is so cheap now that the cost of capital is the main cost component of the levelized cost of solar. By denying solar and wind access to the same tax-advantaged business structures that fossil fuel companies use, governments are protecting the incumbents.

Third, governments provide taxpayer insurance so that energy projects that are not financially viable can get built. The expected cost of a nuclear disaster is in the trillions of dollars. No private company could possibly cover a nuclear accident – so logically there isn't a private market for insuring nuclear power plants. No nuclear reactor would operate without governments providing taxpayer-backed insurance. New nuclear is already too expensive to build even with taxpayer insurance. The U.K. government has fought hard to build the nuclear reactors at Hinkley Point even though they make no financial sense at all. The government has admitted that these nuclear reactors would generate electricity for twice the rate of today's wholesale market – even at today's electricity prices.

Finally, governments protect incumbent energy companies through rules and regulations that raise costs of switching to solar. These regulations can take the form of trumped up charges for the privilege of using solar. Does it make any sense that Arizona, one of the world's sunniest places, approved a charge for the privilege of having rooftop solar connected to



In his latest book, *Clean Disruption*, published in 2014, Tony Seba predicts that the industrial age of energy and transportation will be over by 2030, maybe before.

the grid? Now the state is in the process of changing regulations again to charge new property taxes on rooftop PV. This is in a state with 50% coal usage!

***How easy will it be for countries to embrace new technologies and shut down oil, gas and coal mining operations despite the important role they may play in their economies?***

The incumbent energy companies have waged a misinformation war to spread fear, uncertainty and doubt (“FUD”) about clean energy but the facts betray them. Most job losses in the coal industry happened way before solar was even a blip in the energy radar. From 1980 to 2000 the coal mining industry fired 69% of its workforce even though production went up by 21%. The fact is that in the U.S., the solar industry already employs more people than coal – and solar employment is growing fast. The growth of solar can create jobs for former fossil fuel workers just like the growth of personal computers created jobs for former Cobol or Fortran programmers. The old energy world order was made up of Big Banks financing Big Energy companies to Build Big Power Plants (and Refineries). People had no say at all. Today anyone anywhere can become a solar developer

by tapping many sources of financing, from venture capital to crowdfunding sites. It’s gratifying to see that the “two-guys-or-gals-in-a-garage” culture that built the Internet, personal computer, and mobile revolutions is making its way to energy. Some of these companies, like Solar Mosaic, have grown into fully-fledged financial services companies ready to disrupt the old world order of energy.

To answer your question about industries shutting down their dirty energy operations, they will really have no choice. The Stone Age did not end because we ran out of rocks. Stone tools were disrupted by a superior technology: bronze. Similarly, the horse-and-carriage transportation industry was disrupted by superior technologies such as the internal combustion engine automobile and the electric trolley.

As a society we should protect people, not industries. Instead of subsidizing fossil fuels with \$2 trillion per year and insuring nuclear power plants that could sink a whole country’s economy, governments should insure their citizens and provide a safety blanket that offers a financial cushion, healthcare and educational opportunities as we transition to a clean energy economy.

***Are societies around the globe ready to take the leap?***

Yes. The only people opposed to a cleaner, healthier and wealthier future are the dirty energy companies, their lobbies and protectors in governments.

***The PV and energy storage sectors are becoming increasingly and inextricably intertwined. How long will it be until this convergence begins to have a real impact on conventional utilities and their business models?***

I think that the convergence of solar and storage is imminent. We’re already seeing that solar integrators like SolarCity, inverter companies like Enphase and PV manufacturers like Hanwha Q Cells are getting into storage. Furthermore, we’ll soon see that companies in the electric vehicle value chain will also get into solar storage. What we’ll end up with is the convergence of three industries: electronics (Apple, Google, Foxconn), automotive (Tesla, BMW, Nissan) and energy (solar, wind companies).

In terms of impact on business models, my numbers indicate that by 2020 a household in areas like California (and by extension sunny areas around the world) will be able to generate solar energy for less than the cost of transmission. This means that utilities will not be able to compete with rooftop solar even if they generate electricity at centralized generating stations at a cost of zero. This is what I call “God Parity” which means that conventional utilities don’t have a prayer.

Storage will also be so cheap by 2020 that households will be able to get off the grid for less than they pay for cable TV today. I don’t think most households will get off the grid, but it will be cheap to do it. I think the grid will be closer in architecture to the Internet than the one-way grid today. However, in many areas around the globe it will be financially and technically easy to just get off the grid.

But we won’t need to wait until 2020 for solar plus storage to have a disruptive impact on conventional utility business models. All you need is for solar installations to have one or two hours of storage to destroy the utility’s pricing power. Conventional utilities have a far higher margin on peak prices



than off-peak. By storing just an hour or two of on-site rooftop solar and adding intelligent energy management software and smart devices like smart thermostats, smart inverters or smart air conditioners, you're bringing the traditional utility business model to its knees. Notice that I'm not talking about any breakthroughs here. All these technologies (solar, smart devices, storage) already exist and are getting exponentially cheaper. Storage-as-a-service vendors are already integrating these technologies in easy-to-use packages and financing them over 10 or 20 years. When a critical mass of users adopt these products and take pricing power away from the utilities, you know the end is near for conventional utilities. In Clean Disruption I assume that the cost of storage will be \$200/kWh by

**and desertification. To what extent will energy disruption be able to save China from environmental destruction?**

Coal is sucking China dry. China needs to transition to solar and wind not just because they will help clean up the environment but because the country is literally running out of freshwater.

China is in a water crisis caused by coal's unquenchable thirst for freshwater. The coal industry consumes 23% of the nation's freshwater. This number is expected to grow to 28% by 2020. The government is taking water from agriculture and people and transferring it to the coal industry. Agriculture, for instance, is expected to decrease water withdrawals from 62% of total national freshwater in 2010 to 54% in 2020.



Photo: Bert van Dijk/Flickr

China needs to transition to solar and wind not just because they will help clean up the environment but because the country is literally running out of freshwater, explains Tony Seba.

2020. Grid storage vendor Acquion told me recently that they should be at \$150/kWh by 2018. So things might unravel pretty quickly for utilities that don't change their business models.

***While it may be a dream come true for proponents of renewable energy, what do you anticipate will be the economic effects the disruption of energy and transportation will have on global economies as these major industries collapse?***

Indoor and outdoor air pollution kills seven million people per year. Over a decade that's 70 million people, which is more than any war has ever killed. Fossil fuels also cost taxpayers \$2 trillion in subsidies per year. That doesn't even include the costs of the damage that they are causing to our air, water and lands. Redeploying \$2 trillion per year into things like education, R&D and health care can only bring benefits to the world economy. Saving seven million lives per year, living in a cleaner environment, can only be positive for the world. A clean energy economy is a dream come true for anyone who believes in human rights and human quality of life, not just clean energy advocates.

***China is facing immense problems due to its dependency on coal, from the health of its citizens to increasing drought***

Since the 1950s, China has lost 27,000 of its 50,000 rivers. The numbers that speak to China's water crisis are telling: 400 out of 600 cities, including 30 of the largest 32 cities in China, face water shortages to varying degrees. Ninety percent of city groundwater sources are contaminated, and 70% of rivers and lakes are polluted.

China has 20% of the world's population but only 7% of its freshwater. The fast growth of its industry and population has caused the country to draw unsustainably on its rivers and aquifers. Three-hundred million people in China don't have access to safe drinking water.

To alleviate water concerns in the drying north, China is building some of the largest water projects in its history. The South North Water Transfer Project is a \$62 billion, multi-decade project to divert 44.8 billion cubic meters of water from the Yangtze River basin in the south to the arid north. When you do the numbers, it turns out that most of that water will go to the coal industry, which is located in the arid north.

Solar PV consumes less than a million times the water that coal does per unit of energy. The solar disruption is actually the only way that China can avoid becoming a continental-scale Easter Island. ♦

Interview by Edgar Meza