On the Precipice of the Next Great Growth Cycle & America's Technological Future

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Mark P. Mills
CEO, Digital Power Group
www.tech-pundit.com

Let's start with what all businesses are about; supplying things that people demand. And while this conference, like most engineering-centric conferences, focuses on ***supply***, I plan to focus on the ***demand*** side. But first, I do have a brief observation about supply.

Supplying society-levels of kilowatt-hours is arguably one of the most bizarre challenges of any business. It is the only commodity-class product you can't store.

Nearly everything about how electricity is produced, delivered and managed is driven by this singular fact – you can't store kilowatt-hours in any meaningful quantities. This reality has driven the architecture and engineering – and economics – of electric supply since Edison.

For major commodity flows, you ***need*** to store the product so that the entire supply chain can be effectively, economically and safely managed. And storage is hugely important for moderating price and demand volatility. For society's major commodity inputs – coal, oil, natural gas, gasoline, wheat, corn, minerals – at any given time, throughout the relevant networks, there is in storage about two to three months of annual demand.

The amount of electricity in storage at any given moment amounts to a ***few minutes*** of annual demand. I'm not counting here the geographically isolated and thus limited value of pumped-hydro facilities – which are *di minimis* in any case.

Consequently, electricity has to be produced the instant it is demanded. This of course explains the creation of the collateral and unique industry called "demand side management" – the likes of which doesn't really exist anywhere else.

But for our purposes today, let's focus on the future of ***demand***.

The fundamental thing that determines the future of demand for nearly any industry in America is whether we will see robust economic growth return.

For that, we need to try and predict the future. Given the role of technology in creating our future, we're really talking about predicting technology.

Peter Drucker, the brilliant management consultant famous for his predictions, used to say that he only predicted what already happened. In that spirit, let me predict three things that have already happened, and that portend a very bright, and electrified, future.

Let's start with two facts – two things that have already happened. These two facts contain everything you need to know about the future of the electricity business.

First, in today's America, the share of our economy devoted to moving bits -- ideas and information -- is bigger than the share associated with moving people and stuff.

The "new economy" is already here. Accounting for everything associated with information – from digital movies and server farms, from iPhones and Intel to Netflix and Facebook – we find two trillion dollars of our GDP. All the real growth comes from everything associated with transporting bits.

Compare this with the traditional transportation sector. If we add up everything involved in transporting stuff and people – from making and using cars and airplanes, from F150s to Norfolk Southern and FedEx – it accounts for one-and-a-half trillion dollars of our GDP. And as we all know, this domain grows tepidly.

And the second core fact: The bits-moving industry is, of course, all about electricity. The stuff-moving industry is all about liquid fuels, and oil.

And the bits-moving industries, broadly defined, already consume more electricity than all of the office buildings in America, more than the metals and chemicals industries combined.

These two fact sets, and the trends behind them, say a lot about both the electric business, and about the future of America. After all, the only time in history in which electric demand has declined two years in a row since the Great Depression was in the middle of this Great Recession.

Let's wind the clock back 100 years and look for analogies in long trends. In January 1912 the United States had just emerged from a recession. Who knew then that ***nineteen*** more recessions would follow? But nonetheless, there was a century of phenomenal economic growth. The average American today is in real terms, about 700 hundred percent wealthier than his great grandparent of 1912.

In hindsight it may be obvious that the emerging technologies in 1912 made a long run of wealth growth inevitable – that was the dawn of broad-based electrification and telephony, as well as the automobile age, and the radio amplifier. Observers of that day knew those things were important, but their imaginations failed to grasp the scope of the transformation to follow.

Now in 2012 we are again on the cusp of another comparable transformation. Short-term economic conditions and presidential politics divert our attention. We're on the precipice of another great growth cycle, one that will come from the

convergence of three technological transformations: Big Data, the Wireless Wired World, and Computational Manufacturing.

Again, in Drucker's word, these transformations have already happened, and are beginning to roll out through the economy.

Information technology is undergoing a change as fundamental as the 1980s emergence of the Internet from the already enormous telecom era. We have entered the era of Big Data.

Big Data is driven by the bizarre fact that for all practical purposes, computer processing power and data storage are free. When something truly useful becomes virtually free, growth can be explosive.

Big Data drives a new architecture. The emergence of the Internet – some call it Internet 1.0 – was primarily characterized by the proliferation of personal computing power. The emerging architecture for Big Data – Internet 2.0 -- is epitomized by the proliferation of staggeringly large concentrations of easily-accessible, but physically remote computing. It's called the Cloud.

The Cloud comprises an evolving and growing network of tens of thousands of massive warehouse-scale data centers any one of which would make a supercomputer of a decade ago look positively antediluvian.

As a brief aside, something we'll return to, the Cloud's warehouse scale data-centers each consume electricity at scales that would make a steel mill blush.

The practically free, and nearly instantaneous, data muscle of the Cloud enabled the creation of companies like Facebook and Zynga, and all manner of social media and e-commerce. It will also enable industrial, commercial, scientific and medical revolutions anchored in meta-data analyses. Astronomical feats of data crunching are now affordable, enabling new and previously unimaginable services and businesses. We have so far witnessed only the inklings of what is yet possible.

Maybe we may have lost our capacity for amazement. But just think: An IBM 370 mainframe introduced in 1970 managed the blazing speed of one million instruction sets per second -- or ***one*** MIPS. A modern tablet, an iPad, can process a thousand MIPS, and at one-ten-thousandth the cost of yesterday's mainframe. And in just one Cloud data-center, we pack in the equivalent of tens of thousands of such microprocessors.

The trend in ***storing*** information, not just processing it, is following the same trajectory. In fact, our capacity to store data is getting cheaper and better at a faster rate than computing power. To store a single eBook in 1980 required $10,000 of hardware; today it's under two cents.

Transistors are so cheap and easy to produce now that we manufacture vastly more transistors each year than we grow grains of wheat – not tons of wheat, but ***grains***. The numbers are literally incomprehensible.

No surprise then that a new storage sub-industry has emerged – maybe we should call them the Carbonite-class companies – that is growing at 50 percent a year. People will soon spend more money storing virtual bits, than they do storing physical stuff.

But back to the future that has already happened. Think of Facebook, and similar social media as bellwethers for how commerce is changing – how we are, in effect, changing the Shopping Mall. Make no mistake about it -- Facebook hasn't -- social media is ultimately about shopping and commerce.

Last month in New York City, Facebook held its first-ever marketing conference for businesses. Attendees were reminded that Facebook enables 150 million interactions between its users and businesses, and its news feed generates a billion impressions – per day.

So social media advertising revenues, the equivalent of collecting rent for space in a shopping mall, has surpassed $15 billion. That number already approaches the total revenues collected by all of America's 100,000 Mall owners for renting their physical space.

This is, of course, about much more than Facebook. It is the migration into the Cloud of massive quantities of data and processing across all sectors, from supply chain management to travel, from manufacturing to medical care, to transportation and construction, and to education and healthcare.

The Promethean challenge of the new era of Big Data resides in extracting value and actionable information. Here we find another new sub-industry – even new college degrees – devoted to the algorithms and software to mine and make sense of the exaflood.

Big Data analytics and services, non-existent just a few years ago, is already a $3 billion industry and will be $20 billion in a half decade. Cloud-centric services will drive productivity, and thus collaterally, job growth across all sectors.

We have entered an era where information ***about*** data is more valuable than the data. Where raw data storage and computing power are so cheap that the key now is what to do with it, how to package ***and deliver*** the results.

This brings me to the second macro trend, the delivery – the connective tissue that brings all the compute power to people and businesses.

Fiber optics created the delivery backbone and unleashed Internet 1.0. Wireless broadband similarly unleashes Internet 2.0.

It is already happening. There has never in history been a time when a billion people -- eventually the majority of humans, ***and*** their machines – could effortlessly communicate, socialize, and trade in real time, all the time, anytime, anywhere, with anyone … and any ***thing***.

The economic and social implications of the collapse in the cost of wireless mobile connectivity are as big as those following the dawn of telephony itself. It will introduce both opportunity, and even chaos -- witness the Arab Spring.

And video is the fastest growing part of all the networks. Cisco forecasts a 2,000 percent increase in video traffic over the coming five years leading to more traffic on the Internet in five minutes than there was in all of 1996. Wireless is where a lot of it wants to go.

And, the power implications are huge. Bits are electrons after all.

Some of you probably heard about the kerfuffle over Apple's newest iPad. Awesome with its light-speed connection, faster than home wired networks, and brilliant HD screen. Users find they inhale an entire month's allotment of bandwidth in a day. And the combination – HD bandwidth and pixels -- drains even the high-density iPad battery. Such is the future.

As fast as network providers try to build out, they cannot keep up with demand. Faster is better, and when inevitably cheaper, people will want more.

The third grand technology shift resides in the emerging Computational Manufacturing revolution. This is the first core shift in how we can manufacture things since Henry Ford launched the economic power of "mass production."

We have already seen some evidence of this transformation – a future that is already happening -- in how "automation" has been applied to manufacturing and the supply chain.

But computational-manufacturing is much deeper, and broader. It begins with something more commonly called 3D printing -- or "additive" or direct-digital manufacturing. This is literally the 'printing' of parts and devices directly from a computer model or image, using lasers, electron beams or microwaves, and basic powdered raw materials.

3D printing is radically improving and accelerating the design process, and already produces commercially viable final parts in some niche applications, producing highly customized parts for aircraft, or medical devices like knee joints.

The second half of computational manufacturing, which will make 3D printing economically explosive, happens when it combines with the associated emerging era of computational materials design. Engineers will use supercomputing-power to design and build from the molecular level, optimizing features and even creating new materials, radically improving quality and reducing waste. For example, materials like graphene which offer as much promise as did silicon itself – and bizarre constructs of so-called meta-materials, which enable, literally, features like invisibility.

Computational manufacturing has the potential to be — to use that now over-used word — "disruptive," poised to become a trillion dollar industry

unleashing as big a change in how we make things, as did the agricultural revolution in how we grew things.

It is a manufacturing paradigm defined not by cheap labor, but high talent.

Of course you will hear some say this is yet another form of automation taking away jobs. We've seen this movie before. U.S. manufacturing output *doubled* in the last thirty years. But while the manufacturing labor force decreased, overall employment soared. The recent Great Recession is a temporary sidetrack, a painful one, but one that technology will turn around.

More employment inevitably comes from productivity driving economic growth, not from labor-intensive activities whether in manufacturing, or energy production.

Milton Friedman, the famous economist, made a famous observation about this phenomenon while traveling in China. He saw a large number of men digging with shovels to build a dam. The economist pointed out that fewer men with the right equipment could build more efficiently. But Friedman's host objected; if they did that they "wouldn't be employing the other men." Friedman's response: "Well, in that case, why not give them all spoons?"

Consider that today China and the U.S. have about the same manufacturing output. In China there are 100 million manufacturing workers. In the U.S., fewer than 12 million. China knows full well the trajectory they must be on.

We've been through this before. Roughly a century ago, 40 percent of American workers, 12 million of them, toiled on farms. Technology has enabled a 600 percent rise in agricultural output, and America today has only three million people who call themselves farmers; barely two percent of our workforce.

Still, the Internet and airwaves are full of pundits who say this is all history, claiming growth is over; the last economic miracle of technology is behind us. Gimme a break.

If you spend any time, like I do, talking with and visiting entrepreneurs in small and large companies that are forging tomorrow's Cloud-centric infrastructure and services, you see a blizzard of ideas, technologies and capabilities. All if is bullish for our economy, bullish for America.

And --- it's bullish for electric demand since the economy-driving infrastructure is electric consuming. MIPS, bits, and megabytes all consume kilowatt-hours.

When you, for example, watch Major League Baseball streaming live to your iPad, you are using as much energy as driving about 30 miles in your electric car.

The source of all this demand is in the entire network, not just the Cloud's data-centers - - though they are the most visible. That said, data centers alone already consume more energy that the global aviation industry. We also consume power in communications networks, and in the manufacturing of all the short-lived disposable hardware that comprises those networks.

Info-tech products require an astounding 1,000 times more energy per kilogram to manufacture than the materials that dominated the 19th and 20th centuries. We make far more Droid-like things now than we ever did Dodge-like things – and we cycle through the former much faster than the latter.

When you know all this, you understand why the energy trends look like they do. In America, electric demand rose almost 10% since 2001. That's an increase equal to Italy's entire annual use. That wasn't supposed to happen. We're an efficient ever-more digital economy. Setting aside the Great Recession's drag on demand, we've spent over $20 billion since then to promote and implement programs to stop electric growth.

If it's any comfort for the no-growthers, non-electric energy use *did* decline, about 1%, since 2001.

There is every reason to believe these trends will continue. Soon the majority of our economy's energy will be delivered not by the gallon in pipelines and trucks, but by the kilowatt-hour in wires and batteries.

Consequently, we will enter a new era for information-centric electricity reliability. Ironically, the rising demand for reliability comes at a time when all the measures of grid reliability show it getting worse. This is a subject, and a trend all its own. But back to the fundamental demand paradigm.

Yes, I know the efficiency argument. But advocates of efficiency-as-a-way-to-save-the-planet have it exactly backwards. Efficiency ***creates*** demand.

Consider the car. Automobile engine efficiency improved 500 percent pound-for-pound from early years to the late 20th century. This enabled better, more featured, safer, heavier and more affordable cars. So demand rose, driving a 400 percent increase in transportation fuel use.

True, automotive fuel growth is now flattening in the West as we finally see near saturation levels in road-miles and cars-per-household. But we are a long way from saturation of either IT devices, or of video 'trips' on the information highways.

But back to efficiency and digital engines; measured from 1950, computations per kWh have improved ten **trillion**-fold. And that's exactly why so many more data-machines got built. And why the total amount of electricity used to perform computations has increased 300-fold since then.

Without more energy-efficient logic engines, storage and transport, there would be no Google or iPhone. At the efficiency of computing of the 1980s, one Google data center would consume more electricity than Manhattan.

One place where efficiency mavens and I agree – a whole lot more computational efficiency is on the horizon. And it will drive up demand for both electricity, and reliability.

Which brings me back to your industry, and its future.

Today's electric industry is already beset by daunting challenges. Tomorrow's will have to make a fundamental shift in architecture to accommodate the new scope, scale and character of electric demand in the emergent economy.

Despite all the smart grid hype -- today's electric grid still resembles yesterday's broadcast TV industry circa 1960. Pretty much one size fits all, with limited variants in content, or how and when you could receive anything. It is a top-down distribution system.

The electric industry will need to evolve into a radically new infrastructure that is interactive, on-demand, storable, flexible. In other words, the goal is not just to use the Internet to add information *about* the grid, but to have the grid operate ***like*** the Internet. This is much more difficult, but possible. Much of the enabling technology emerges directly from information-technology itself.

Let me wrap up with one last observation of the tenor of the times we live in.

Of course the Internet is already huge. But so was the auto industry in 1952. America already made a lot of cars, and the automobile ecosystem consumed a lot of steel, rubber and related materials and services, and energy. And yet that sector grew enormously, literally driving the American economy.

It may be 2012, but for the Big Data and the Cloud, it's only 1952.

There is no doubt that our country's future is bright. You could say, ladies and gentlemen, it's time to start your engines.

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