Electricity 2.0: Unlocking the Power of the Open Energy Network (OEN)

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Table of Contents

Executive Summary

America and the world stand on the brink of a revolution. That revolution—in how the world creates, trades, and consumes energy—has the potential not only to aid the environment but also to lower the risk of war, create wealth, democratize energy, and empower people everywhere as never before. While this revolution is generally associated with the term 'clean energy', the issue is deeper: How to reinvent the energy network and democratize global energy.

Many fuel sources make up the world's energy supply, but at its heart lies one network—the electricity network. Electricity forms the backbone of the world's wider system of energy exchange because it is electricity that links other networks, such as oil shipments, gas pipelines, and coal trains. It is electricity that converts the energy captured in prehistoric plants, rushing rivers, and the atom into flowing electrons and enables that energy to move not at the speed of a tanker or truck but virtually instantaneously. It is thus unique in allowing falling water in one time zone, for example, to light up a city in another.

Like other networks—the telecom network, the network of roads and rails, and commercial networks—the electricity network or 'grid' creates value by linking people. However, heavily regulated, undersized, short on intelligence, and long on red tape, today's grid has become a barrier to the clean and efficient flow of energy.

While the network has many physical deficits, its real problem is not physical at all. Its real problem is systemic: It is supported by a system that, rather than encouraging change and innovation actively thwarts them. Many problems afflict the current system, including bias against new clean technologies and renewable power. But all such problems share a common solution: Tear down the walls to the energy network.

To understand why progress in the United States has been so elusive, NDN and the New Policy Institute embarked upon an extensive study of the implementation of clean power and technology in America. Our findings suggest that the slow progress to date is not due to a lack of will or money but, rather, to a central and pervasive problem—the structure of the power industry in the United States.

Our research suggests that key structural roadblocks are blocking progress. These roadblocks stem from the extraordinarily complex structure of the American power industry, and they are blocking the uptake of clean technology and the deployment of renewable resources.

A Call to Action

Without action designed to remove these roadblocks, our analysis suggests there will be no renewable energy revolution in the United States. America will remain hostage to foreign fossil fuels, fail to make real progress on lowering greenhouse gas emissions, and cede leadership in the next great wave of innovation to rival countries.

This very real possibility is especially tragic because the electricity network is on the cusp of undergoing a period of profound change and renaissance that one might call 'Electricity 2.0'.

As with the first wave of electricity innovation, Electricity 1.0 over a century ago, rapid advances in technology and materials have created an immense opportunity. Information technology, a better understanding of networks, advances in silicon technology, nanotechnology improvements, enhanced power storage, structural change in the auto industry, and new work in electromagnetic fields and circuits all have the potential to usher in a period of profound growth and wealth creation built on an open electricity network.

Potential new services include not only green power but automated power management, power continuity, micronetworks, distributed generation and storage, integration of cars with the network, and peer-to-peer power sharing. But this can happen in the United States only if the existing industry structure undergoes deep and fundamental change.

To be sure, Electricity 1.0 served the world well. In its day, it sparked inventions from the light bulb to the computer. After 1907, as states adopted regulation, it largely succeeded in its goals: Contain short-term costs, increase reliability, and, from the 1930s onward, cover rural areas.

However, meeting those goals came at the expense of innovation which, outside nuclear research, slowed to a trickle. It also came at the expense of network capacity, which declined in real terms, and of technical breakthroughs, which became fewer and fewer. This caused the virtual disappearance of any new products and services. The net result has been to freeze the network in time. But we can no longer afford to live in the past. The time has come to upgrade to Electricity 2.0.

The Road Forward

It is time to revive innovation in the power sector. It is time to empower the American people—who care about the climate, about security, and about higher standards of living—to produce, buy, and sell the energy they desire. It is time to unlock the full economic potential of an Open Electricity Network (OEN) and the new goods and services such a Network can provide. By overlaying on physical wires a new open network, a vastly expanded pool of participants will exchange energy as they currently trade other goods, services, and knowledge, dramatically increasing the entire network's value.

With a new open architecture and incentives to restore innovation and revive investments, Electricity 2.0 promises to do for energy what the Internet did for communications. By opening up the network to renewable energy, adding storage to make the network resilient, and empowering participants to interact with one another, the OEN will facilitate unprecedented types and quantities of transactions. But, just as the creation of the Internet required substantial revisions in the framework governing telecommunications, Electricity 2.0 will require fundamental regulatory reform.

Recommendations

We propose a Big Bang to consist of reinvention of the entire architecture governing the Electricity Network to unlock the economic promise of the Electricity 2.0.

- While not abandoning state regulation, the industry must move toward streamlined regional and national regulation that matches the borderless configuration of the network itself.
- Utilities must be freed to engage in more unregulated energy commerce outside the rate-based system. But, to spur utilities to innovate and ensure they do not exercise market power, competition must be extended far more deeply at the retail level and extended geographically to create new companies, drive innovation, and accelerate job creation.
- The network must be opened to more participants, vastly expanded and modernized, and equipped with open plug and play standards to facilitate its secure but widespread public use.
- We propose the creation of a new electricity commerce network to be overlaid on top of the physical network and the encouragement of a second, low-voltage wire into the home—to be provided by other common carriers, such as telecom companies or new market entrants.

To accomplish these goals, NDN proposes the following steps:

- President Obama should charter a commission comprised of network and electricity experts with the mandate to design a new open architecture to support Electricity 2.0 based on the three principles of empowerment of the American people, open network design, and broader and deeper competition.
- State regulators, the Federal Energy Regulatory Commission, utility executives, technologists, and other stakeholders must undertake a parallel effort to devise a new open architecture for Electricity 2.0.
- Congress, in conjunction with the Administration, must pass legislation to update and reform the American electricity industry.

Finding the right balance between opening up the network, securing it, expanding it, adding functionality, and protecting the rights of investors and consumers will not be easy. But it is work that cannot be postponed. If America is to realize the promise of Electricity 2.0 it must reform the existing industry, as it did in telecommunications and transportation, and create a new, open energy network architecture that democratizes energy and empowers the American people to prosper in the 21st Century.

I. Introduction

America and the world stand on the brink of a revolution. That revolution—in how the world creates, trades, and consumes energy—has the potential not only to aid the environment but also to lower the risk of war, create wealth, democratize energy, and empower people everywhere as never before.

The term sometimes used to describe this revolution is 'clean energy'. But the term clean energy does not do justice to the value that reinventing the world's energy system would create nor the changes needed to unlock it.

Many fuel sources make up the world's energy supply, but at its heart lies one network—the electricity network. Electricity forms the backbone of the world's wider system of energy exchange because it is electricity that links other networks, such as oil shipments, gas pipelines, and coal trains. It is electricity that converts the energy captured in prehistoric plants, rushing rivers, and the atom into flowing electrons and enables that energy to move not at the speed of a tanker or truck but virtually instantaneously at the speed of light.[1] It is thus unique in allowing falling water in one time zone, for example, to light up a city in another.

Despite this central role in the world's energy network, however, the electricity grid, as it is called, has become a weak link. Antiquated, static, and burdened with regulation, it has become a creaking barrier to the clean and efficient transfer of energy.

To understand what is holding the United States. back despite decades of talk about replacing fossil fuels with renewable energy, earlier this year NDN and the New Policy Institute began work on a top-to-bottom, in-depth study of the electricity network, including its growth, its status today, and its policy and regulatory framework in order to understand why the U.S. is lagging behind other countries.

After interviewing numerous leaders, conducting extensive economic and quantitative analyses, and studying the history not only of electricity but also of other economic booms as well as the impact of regulation on business growth, our conclusion is that there is one major roadblock to a renewable energy revolution. That roadblock is the current structure of the U.S. utility industry. We believe that, without reforming that structure to remove the roadblocks it imposes the United States will fail to realize the potential of Electricity 2.0.

The key to realizing the promise of clean energy is to reinvent the backbone of the world's supply, the electricity network, and upgrading from Electricity 1.0 to Electricity 2.0. The key to achieving Electricity 2.0 is reforming the system that created the existing network.

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[1] In an electric circuit, energy moves at speeds that can approach that of light for some conductors, such as metal wire. However, the actual electrons move very slowly (at about the rate of the minute hand of a clock) in the case of direct current or not at all in the case of alternating current. When a current starts, each electron knocks the one next to it—transmitting energy to the last electron very rapidly—although the electrons barely move, in a manner analogous to a wave passing through water in the ocean.

Electricity 1.0 served the world well in its day. In its early years, it unleashed stunning technical advances including the phonograph and radio, and it also moved the world first into the transistor age and now through the computer revolution. But Electricity 1.0 has been static now for many years. Electricity 2.0 promises to revive innovation in the power industry and make it once more an engine of prosperity.

The electricity grid—a term that reflects the static nature of Electricity 1.0—is fundamentally a network. Like other networks—the telecom network, the network of roads and rails, and financial and commercial networks—it creates value by linking people. Its value grows with the connections between producers and consumers created by it. Until recently, however, the electricity network has been a closed private network, open only to a small group of highly accredited players.

The central project of Electricity 2.0 is to unlock the economic potential of the energy network by overlaying on physical wires a new, open network able to connect a vastly expanded pool of participants and allow them to exchange energy as they currently trade other goods, services, and knowledge.

The problems of the current system are many, including undersized wires, poor network design, lack of rural reach, and lack of intelligence. The solution turns out to be singular: Tear down the walls to the energy network.

With a new, open architecture and incentives to restore innovation and drive new investments, the Open Electricity Network promises to do for energy what the Internet did for communications or what computer technology did for finance. By opening up the network to renewable energy, adding storage to make the network resilient, and empowering participants and nodes to interact with one another, the OEN will facilitate unprecedented types and quantities of transactions. It will ultimately empower people as never before.

However, like the Internet, financial services, and other updated industries the OEN will not be built from scratch. Rather, it must be grafted onto an existing, functioning network of legacy investments, locked-in technologies, and assorted biases that flow from an incumbent structure.

The creation of the Internet required substantial revisions in the framework governing telecommunications. Financial services, similarly, required major changes to regulations. In the same vein, Electricity 2.0 will not appear on its own or without fundamental changes in its regulatory framework.

As with communications and finance prior to their revolutions, huge roadblocks stand in the way of Electricity 2.0. After a period of magnificent innovation, the power industry from 1907 onward coalesced around an increasingly rigid system that stressed three goals at the expense of all others.

As states adopted regulation they strove to contain short-term costs, increase reliability, and, from the 1930s onward, extend the electricity network to rural areas. However, meeting those goals came at the expense of other objectives—innovation, which outside of nuclear research slowed to a trickle; network capacity, which has declined in real terms; breakthrough investments, that might have dramatically lowered costs; and the virtual disappearance of any new products and services. The net effect after decades has been essentially to freeze the network in time.

After a long hiatus, it is time to revive innovation in the power sector. The private sector must be freed to do most of the work. But Electricity 2.0 also requires government leadership to reform the current regulatory environment and, afterwards, to solve problems that the market cannot resolve on its own.

Important biases exist under the current framework to innovation, to the purchase of new technology, and to renewable technologies. The network must be opened to give these technologies the opportunity to flourish.

Finding the right balance between opening up the network, securing it, expanding it, adding functionality, and protecting the rights of investors and consumers will not be easy. It was not easy in the case of telecommunications, finance, or transportation. But it is work that cannot be postponed, lest America sacrifice leadership in realizing this historic opportunity.

In the pages that follow, I will begin by summarizing the benefits of clean energy and Electricity 2.0. Then I will identify the obstacles blocking Electricity 2.0 and a renewable energy revolution, analyze the structure of the electricity network as it has developed historically, and outline the structural obstacles it is necessary to change. Finally, I will lay out the policy and legislative steps needed to create the Open Electricity Network and unleash all of its economic potential.

If America is to realize the promise of Electricity 2.0 it must reform the existing industry and create a new, open, innovation-friendly network architecture. While the promise of action is great, the cost of inaction is severe. To delay is to darken America's future.

II. The Potential Benefits of Electricity 2.0 and the Renewables Revolution

There is wide consensus among policymakers, stakeholders, and the American public regarding the environmental, security, and economic benefits of moving America toward a cleaner energy future. Clean, renewable, domestic energy has the potential to do everything from reduce geopolitical stress over finite resources to reduce mercury levels in fish to solve the existential problem of climate change. It can also lower the trade deficit.

Yet, beyond enabling the deployment of clean technology and unleashing the renewable revolution, Electricity 2.0 promises to yield even greater benefits to our economy. By opening up the network to new participants, goods, and services—democratizing energy and empowering consumers—Electricity 2.0 promises to drive a second wave of wealth creation, create new domestic jobs, and raise standards of living for years to come.

Environmental Benefits of Clean Energy

Electricity generation currently releases greenhouse gas emissions, creates radioactive waste, and releases other pollutants into the air, most notably particulate matter from coal and mercury. Electricity 2.0 reduces or ends such adverse environmental impacts.

Greenhouse gases. The power industry generates about one-third of all U.S. greenhouse gas emissions (with cars, industry, and buildings producing the rest). Coal-fired plants produce the bulk of these (about 83%) or about 27% of America's annual greenhouse gas emissions. Reducing U.S. coal emissions by just 10% through clean coal, replacing coal plants with alternative sources, or simply reducing demand would therefore translate into a 2.7% reduction in U.S. greenhouse gas emissions.[2] Reducing the power-derived greenhouse gases from natural gas and oil would further lower overall emissions. Since the world is on course to burn more coal in years and decades ahead, clean technologies should have an even larger impact going forward.

Beyond the direct impact of reducing greenhouse gases released in power generation, Electricity 2.0 promises to reduce greenhouse gases from transportation, industry, and buildings as a revived electricity sector powers more cars, industry generates, shares, and uses power more efficiently, and buildings implement Electricity 2.0 methods of using electricity (as discussed below).

Mercury and other pollutants. Greenhouse gas emissions that aggravate the climate are not the only harmful environmental impact of power generation. Fossil fuels release particulate matter and other pollutants that, when burned, kill thousands annually, while nuclear power, though emissions free, creates the familiar risks associated with radioactivity and warm water from cooling turbines. Leaving aside long-term issues associated with the transfer and storage of spent nuclear fuel and waste and the huge, if rare, cost of nuclear accidents, pollutants from burning coal entering the air and water comprise one of the world's largest and most pervasive environmental challenges.

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[2] EIA data. For a further breakdown see http://www.eia.doe.gov/oiaf/1605/flash/flash.html.

A recent National Resource Council report estimates coal-fired, electricity-induced damages to the environment to equal on the order of 3.2 cents per kilowatt hour. Particularly harmful to human health is the release of particulate matter into the air.[3]

While acid rain from SO_2 emissions has been reduced through a cap and trade system implemented in the 1990s, mercury trapped in burning coal continues to enter the atmosphere and, from there, our water. Mercury from coal-fired plants is the main source of unhealthy mercury levels in fish. Indeed, in less than a century the once clean oceans have become so contaminated with mercury—most of it from burning coal—that the Food and Drug Administration now recommends that pregnant women and children consume tuna, swordfish, and numerous other species—otherwise exceptionally healthy food choices—no more than once a week. Under 2005 Environmental Protection Agency rules, utilities are slated to reduce mercury emissions from 48 tons per year to 15 per year in 2018. The accelerated deployment of technology to scrub smokestack emissions and the replacement of coal-generated electricity with alternative power will be critical to meeting this goal, let alone implementing stronger standards.

The Security Benefits of Electricity 2.0

In addition to its environmental benefits, Electricity 2.0 promises to contribute to America's national security in fundamental ways.

The U.S. power industry, unlike our transportation industry, already relies on domestic fuel. Hydropower, coal, nuclear energy, and natural gas are all domestic in origin and, as is often pointed out, the U.S. has large reserves of natural gas and still larger deposits of coal. Continued independence, however, is subject to caveats. Coal, while abundant, is concentrated in the West and mountainous East, constrained by rail connections, and not available economically at every location. While the U.S. natural gas market is currently isolated from the global one, a changeover from piped to liquid natural gas (LNG)—which could happen if large, proposed LNG tanker ports get built—would connect the U.S. with the global market. If so, LNG from abroad might one day prove cheaper than the domestic variety, as is the case with oil. (Technically speaking, the U.S. has abundant oil. The problem for energy security is that the foreign variety costs less.) Small differentials in the global price of liquid natural gas if the U.S. globalizes its gas consumption could lead to the loss of natural gas independence at some future point.

While the U.S. currently remains energy independent in electricity, a tight electricity market threatens to prevent the U.S. from using more electricity at the expense of oil. Electric cars—which could make a huge dent in oil imports—will task the current system unless more power can be brought on line. Clean power from wind and the sun could help eliminate this constraint on the use of electric cars. So, indirectly, an improved electricity network will contribute to energy security.

However, Electricity 1.0 poses additional security risks that Electricity 2.0 is needed to fix.

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[3]See *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use,* National Academies Press, 2009; http://www.nap.edu/catalog.php?record_id=12794.

Centralized, large-scale power generation is vulnerable to military or terrorist attack. The destruction—or interruption of a large coal-fired plant by terrorists—could lead quickly to the breakdown of social order insofar as everything from the pumping of fresh water and the disposal of sewage to banking and phone service depends on electricity. The problem is aggravated by a lack of redundancy in the network, minimal storage, and no self-healing capability.

Nuclear power plants also provide an obvious military and terrorist target. Since the first nuclear power plant was opened in 1956, fortunately only a handful of countries with nuclear power have been involved in wars and no nuclear power plant has been damaged during a war. However, the consequence of damage, whether by terrorism or war, to a nuclear power plant has the potential to be catastrophic. Nuclear power plants also present opportunities for countries to enrich fuels for the purposes of making weapons.

While the renewable alternatives to baseload coal and nuclear power pose challenges of their own, namely scale and variability, the same logic that led the military to invest heavily in the Internet—despites its cost and an existing network of dedicated wires—to provide decentralized, backup communications in the event of an attack or critical outage argues for Electricity 2.0 to upgrade redundancy, improve network design, and provide a large measure of distributed capacity and fault tolerance to improve network resilience.

The antiquated infrastructure of Electricity 1.0 due to its long period of undercapitalization has created numerous security risks. Updating the technology, capacity, redundancy, architecture, and security of the network will improve America's overall national and homeland security.

The Economic Benefits of Clean Energy

Electricity 2.0 promises significant benefits to the economy from a variety of sources.

First, the introduction of new, renewable power is a major economic creator of wealth in and of itself.

The physical construction of wind and solar power is localized and labor intensive and, therefore, in its early construction phase adding renewable power to the network has a large regional multiplier effect. Longer term, wind and solar power require little manpower. However, the construction of new wind farms and solar fields and the process of connecting them to the network drives considerable economic activity up and down the value chain. Since solar energy can be used at small scale in distributed locations, the installation of solar facilities promises to have a wide geographic and sectoral impact.

Second, a broader market and footprint for renewable power will stimulate investment in new renewable technologies. These may include new varieties of thin-film solar, new clean coal technologies, new electricity storage technologies, new emissions cleaning and scrubbing technologies, entirely new fuel technologies (using, for example, algae, nanotechnology, and biogenetics), and other technologies that will build the clean energy infrastructure of the future.

Electricity 2.0 will thus drive a great deal of new technology development and high-paying, high-tech jobs.

Third, a broader market will also stimulate the manufacture of solar panels, thin films, turbines, and other energy products. It is well documented in the economics literature that manufacturing jobs in the high-tech sector pay, on average, considerably more than jobs in other sectors of the manufacturing industry.

Fourth, Electricity 2.0 will require substantial investment in and upgrading of the nation's power infrastructure. The design, building, and fulfillment of new lines, switches, software, systems, and related products will constitute a large economic project in and of itself that will generate jobs and economic activity. The market for new smart switches, meters, and wires will not only drive spending on existing solutions but also drive investment in new and improved technologies, such as superconducting wire now being tested on Long Island, value-added software, and other products not yet envisioned.

Additional Benefits from Electricity 2.0

The question of who leads the world in opening up the electricity network is of no small importance because the country that does so will sit at the center of the network, drive its standards, develop its first products, and harvest the lion's share of its value. Just as U.S. leadership in Internet technologies led to industries employing millions at higher than average wages, so Electricity 2.0 and the OEN revolution can create similar opportunities for the nation and people that lead it.

Electricity 2.0 will provide economic benefits by introducing new products and services and empowering participants in the network—everyone from large industrial consumers to electric device manufacturers to consumers—as never before

Electric appliance manufacturers will gain a new platform for product and service innovation. Smart homes and appliances, power assurance technology, low-voltage and direct current lines, joint information and power standards, micro-grids and power storage, and sharing technologies will create opportunities for companies and entrepreneurs to devise new products and services that leverage the network.

Second, it is customary when speaking about the electricity network to talk about the grid. The word 'grid', however, does little justice to what is really a *network*, the network at the center of the broader energy network. Like other networks—the rail network, the road network, the telecommunications network, and the world's global financial network—the electricity network creates value by linking consumers and producers. The electricity network connects people as surely as a telephone line or Internet connection. It literally transfers the power of water crashing over Niagara Falls to the outskirts of New York City and of sun striking the Nevada desert to homes in California. Because of how it has been organized, it normally transmits power collected in one place to users distributed across many places, but there is no reason it could not collect power from many places and shift it to one place or shift power from one house to a neighbor's house.

Networks create wealth and economic value through the two main ways that people and goods interact economically: By facilitating trade and by what economists call externalities—the positive value that complementary products, technologies, and goods grant one another. The economic benefits of both are well documented in the economics literature, but consider what they mean in practice.

Most people prefer variety in their goods. When one person with tea trades with another person for sugar, both are better off from the bargain. In addition, since some people or places can make things better or more cheaply than others based on things like skill, the weather, or the fertility of the soil, trade allows people and places to focus on what they do best.

When complementary goods and knowledge come together, they accomplish the similar miracle of creating value. A wine shop enhances the value of a cheese shop next door. One phone is useless, but a second, third, and fourth enhance its value by allowing people to communicate. Networks create wealth by lowering the cost of trade and connecting people and goods. In this they are aided by standardization, since standardization makes it easier for different people in different places to work together. Standards, in a way, define a network. In contrast, multiple competing standards create a Babel of confusion between smaller networks that reduces overall welfare. However, one standard can also limit innovation if it prevents other interaction that could be economically beneficial.

Experience with electronic networks has led to an improved understanding of how they work and can be enhanced by providing one to many, one to one, many to one, and, of course, many to many connections. Generally, the more participants in a network and connections between them the greater the network's value. And, one might add, the greater the connections at any one node or hub the greater the value of that node.

Electricity 2.0 will empower participants on the network as never before. Companies with warehouse rooftops able to collect solar power, waste that can be burned to provide the power for an industrial park, or open land suitable for wind turbines will gain the ability not only to service their own needs but provide power to others. Some may choose to contract to a third party to exploit those resources for them. Industrial parks, office parks, and even communities, currently barred by law in many cases from sharing power, will gain the ability to share power over microgrids. Distributed storage across the network will allow consumers to collect power when available and time-shift it to periods of the day or year when it is required.

Third, Electricity 2.0 is a vital link in the chain to connecting the electricity network with transportation. Without a dramatically upgraded and open electricity architecture, it is doubtful that electric car transportation will achieve critical mass in the near term in the United States. However, with Electricity 2.0 car batteries integrated into the network will provide a large repository of power storage and source of resilience. Indeed, to put the car battery storage opportunity in perspective, by some estimates car batteries could store 14 times the entire electricity generation capacity of the United States. However, for batteries to do this job they will have to be networked through a smarter, flexible, electricity network, and so this opportunity, also, is dependent on Electricity 2.0. The linkage of the energy and transport sector will be a huge drive of job creation, wealth, and new products and services as part of the renewable revolution.

Fourth, Electricity 2.0 will drive economic activity in a variety of ancillary sectors, as in the financing of new power installations, the creation of new methods of selling and trading power, and the managing of the network through innovative methods of demand response.

All told, therefore, Electricity 2.0 is not just vital to the entire clean technology project. It holds the promise of creating new business opportunities, democratizing energy, and empowering consumers as never before.

III. Progress So Far

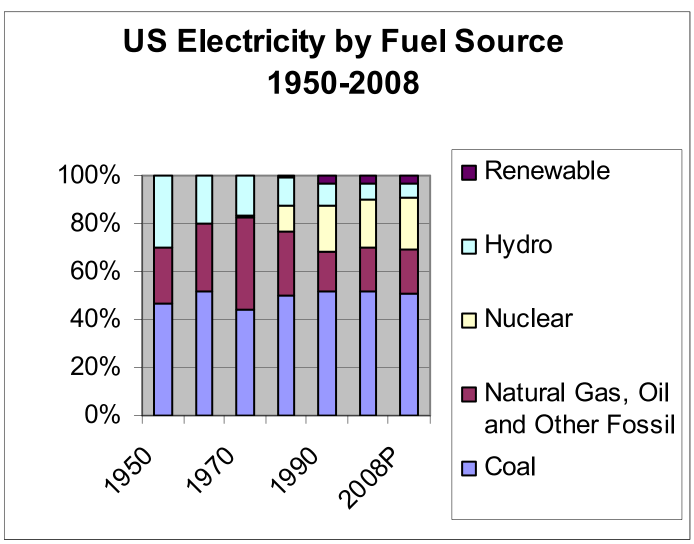
Despite global concern about climate change, decades of talk about energy security, and the huge potential benefits of clean energy, change in the power energy industry has been excruciatingly slow. In the core metric of producing clean power, the U.S. now lags behind other countries—Germany, Spain, Denmark, and Portugal—on a per capita basis and also in market share in key technologies. The U.S. lags behind competitors in many cases by an order of magnitude. Laboring under the restrictions of Electricity 1.0, the U.S. is no longer an energy leader. It is important to note that this is a very different vista than the U.S. faced prior to other recent technology revolutions, where the U.S. entered the race in the lead.

The U.S. does lead in certain niche technologies that hold the key to catching up, such as thin-film solar and bleeding edge energy storage. But unless the current system is changed we will continue to face major headwinds. A progress scorecard to date in implementing clean energy and updating our energy network reveals that bright spots are few and far between.

Deployment of Renewable Power

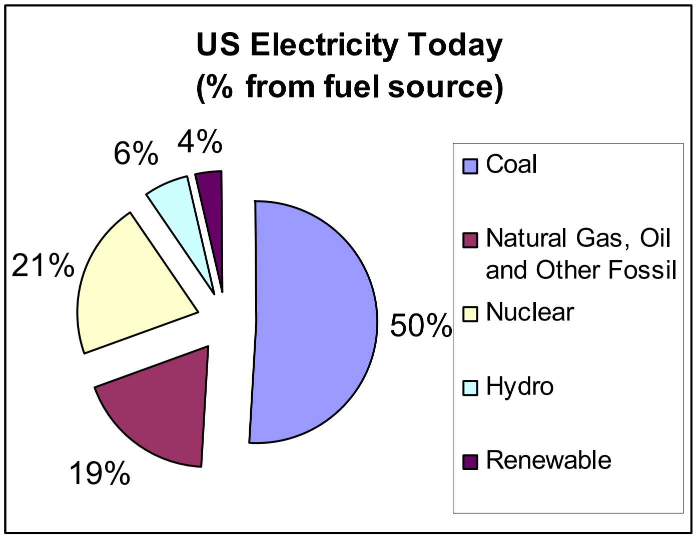
Figure III-1 shows U.S. electricity production by the fuel used to produce it since 1950. As is readily apparent, coal has produced approximately half of all our electricity since 1950. Indeed, coal has been the mainstay of power generation since Edison's Pearl Street Station fired up in 1882. Hydropower, successfully introduced at Niagara Falls in 1895 and the second oldest power source, accounted for about a third of electricity production in 1950 but today, as Figure III-2 (next page) shows, produces only about 6% of the total. While our total power needs have grown, most of the good hydropower sites in the U.S. were exploited by 1950, offering little opportunity to expand. Nuclear power, which began to come on stream at the end of the 1950s, expanded rapidly in the U.S. until 1979, when the Three Mile Island accident caused utilities to cancel or put on hold most projects. Existing sites have been expanded, but no new nuclear site in the U.S. has come on line since 1996. Nuclear plants currently supply about a fifth of U.S. electricity.

Figure III-1



Source: Energy Information Agency

Figure III-2



Source: Energy Information Agency

Natural gas has declined in importance as a source of electricity but remains a large component. Though an efficient and attractive alternative to coal insofar as it burns cleanly, natural gas combustion produces CO_2, if not particulate matter, as a product. Favored by merchant producers in the "Dash to Gas" of the 1990s, its business proposition has proven vulnerable to the price volatility of gas over this period and the rising long-term trend line of its price.

In contrast to the larger sources of power, non-hydro renewable power from wind, solar, and biomass, while grown from a small base, remains modest at 3.5% of the total. Wind energy has increased year after year from a small base, but currently it only supplies 1.3% of U.S. power. Solar energy supplies .002 % of U.S. power. Geothermal energy supplies .8%. And power from burning wood and waste supplies .9% and .6% of demand, respectively.

Progress in bringing renewables on stream in the U.S. has been so slow that one might be tempted to say clean energy is never going to make a major dent in the electricity market and that one federal pronouncement after another—beginning with the recommendation of the 1952 Paley Commission to invest in solar rather than nuclear power—has been hopelessly overoptimistic about its potential.

Pessimism is belied, however, by the progress made by other counties that have made sustained national commitments to renewable energy.

- Germany more than doubled its use of renewable energy, from 6.3% of the total in 2000 to 15% in 2008;
- Denmark increased its use of renewable fuels nine-fold between 1990 and today, from 3% to about 28%; and
- Spain lifted the renewable share of its electricity from 20% in 2006 to 35% today, with some regions such as Castile and Leon producing 70% of their electricity from renewable sources.

As Figure III-3 and Figure III-4 show, while the U.S. currently ranks first worldwide in installed capacity of wind, on a per-capita basis it is only fifth.

Figure III-3

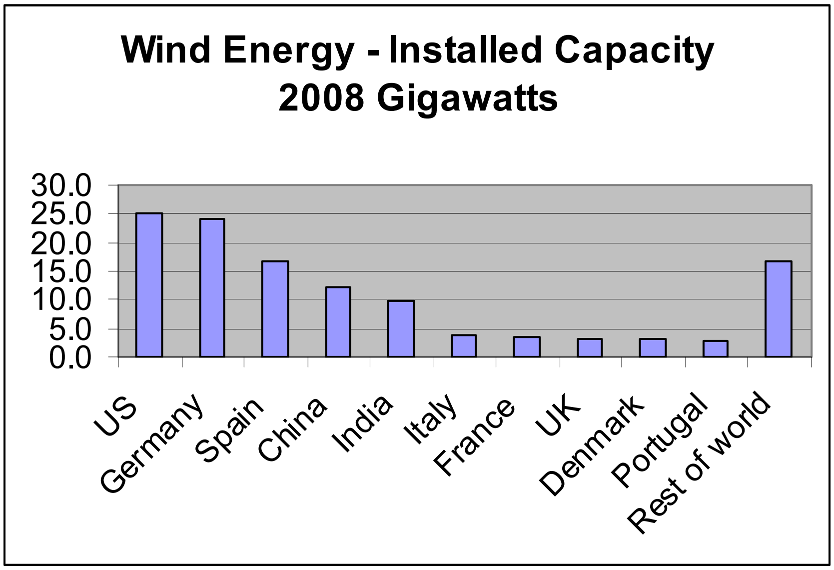
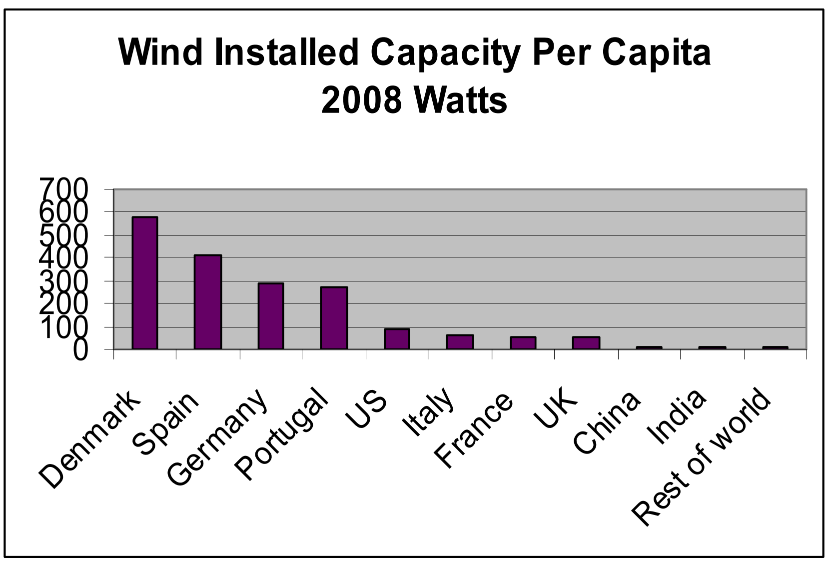


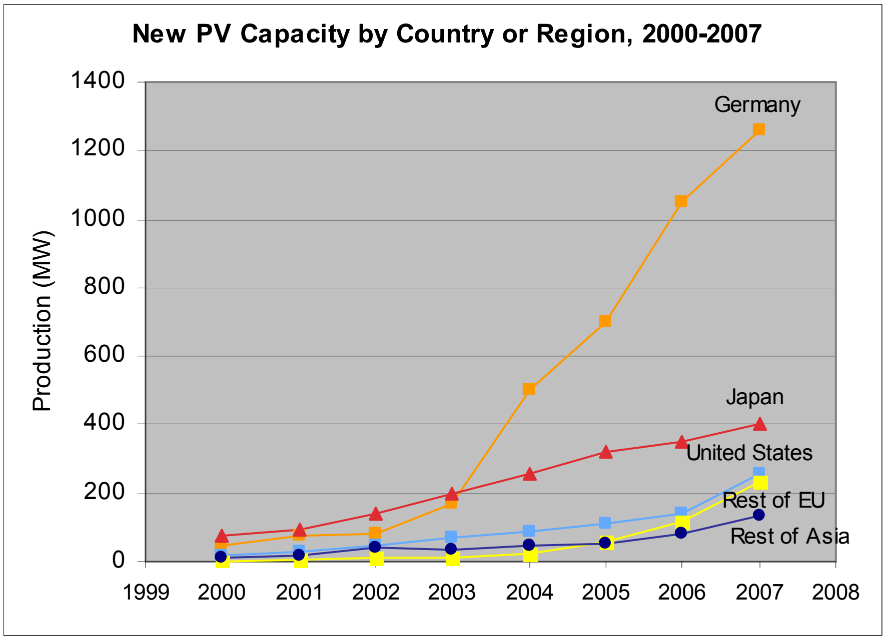
Figure III-4



Sources: GWEC (wind capacity) and CIA Factbook (population)

United States progress to date can also be measured against what experts believe we could be doing. Wind energy alone could supply at least 20% of our needs according to a Department of Energy estimate. While renewable energy is unlikely to ever supply all of the nation's needs, as it does at some hours of the day in some parts of Denmark, it should be able to provide up to a third of U.S. needs once fully developed. Figure III-5 (next page) shows how the U.S. is similarly lagging behind other countries in the installation of solar capacity.

Figure III-5



Source: Prometheus Institute, PV News

Leadership in Clean Technologies

Many in Silicon Valley and elsewhere say clean technology and renewable energy will drive wealth and prosperity in the 21st Century, but despite the vaunted U.S. system of innovation the U.S. is not playing a leadership role. Indeed, by many measures, the U.S. is barely even in the game. United States companies lag in the production of solar panels, wind turbines, and conventional lithium ion batteries, to name just a few well known products. Only in a few cutting edge technologies discussed below is the U.S. in the lead.

By comparison, U.S. companies pioneered many mainstream environmental technologies. For example, in implementing coal washing prior to combustion as well as technologies like electrostatic precipitators, fabric filters or baghouses, wet particulate scrubbers, and hot gas filtration systems to remove particulate matter, U.S. firms have been leaders. To combat SO_2 emissions, U.S. firms pioneered flue gas desulphurization technologies, and to lower NOX emissions utilities have deployed primary abatement technologies including low NOX and high-efficiency burners and also secondary technologies such as Selective Catalytic Reduction (SCR) and Selective Non-Catalytic Reduction (SNCR) that remove NOX from flue gas.

However, despite a venerable record of developing these technologies and the long U.S. history of generating electricity from coal, the U.S. no longer enjoys leadership in creating state-of-the-art coal plants. China, as part of its breakneck construction of coal plants to keep up with demand as its economy has soared in recent years, has begun building the world's highest efficiency coal plants that harvest approximately 45% of the energy in coal using ultra supercritical hot steam technology. This surpasses the 40% yield achieved at the most efficient U.S. plants.[4] High yield is important because it reduces the quantity of coal needed to produce an equivalent quantity of electricity.

If the U.S. is to regain leadership it can only be through leapfrogging existing technologies with more advanced approaches. In other industries, such as software and electronics, the U.S., with its vaunted system of technology innovation, has excelled. Clean technology is now the second largest investment category for venture capital in Silicon Valley, and U.S. firms are pioneering promising clean technologies.

- Thin-film photovoltaic solar dominated by U.S. firms is challenging conventional crystalline solar dominated by Japanese and Korean firms.
- The high-density lithium ion batteries based on nanophosphate chemistry pioneered by A123, a U.S. company with manufacturing operations in Asia, are challenging conventional lithium, ion, and nickel metal hydride batteries.
- U.S. firms developing grid management software, such as Silver Spring networks and Gridpoint, enjoy substantial market share.
- U.S. firms such as Enernoc are pioneering demand-response solutions.
- The U.S. venture-backed carmaker, Tesla, has engineered and pioneered many electric drive technologies in its Roadster sports car.

In fact, U.S. firms backed by the Silicon Valley venture capital community are pioneering a wide range of clean technologies with transformative potential in such fields as energy production, energy efficiency and storage, demand response, and transportation infrastructure. The first Global Cleantech 100 list of the world's most promising companies, compiled by the Cleantech Group and the UK-based *Guardian* newspaper, found that 55 of the 100 companies were U.S.-based. Clean technology has been the recipient of a large quantity of venture capital investment that totaled $5.6 billion in 2009.[5]

However, as a general rule, companies developing these technologies have found that getting these technologies to market is quite difficult. Utilities are perceived as tough customers to market to. Indeed, the entire sector has been slowed in its development by the difficulty of selling to an industry unaccustomed to innovation where expenditures are carefully scrutinized not only by the utility itself but by regulators charged with protecting the consumer.

In fact, as we shall see, it is no coincidence that U.S. firms developing clean technologies are finding marketing and sales of their technologies so difficult. There are solid structural barriers in place, an artifact of the highly regulated structure of the utility industry acting to slow or even block outright the adoption of advanced technologies.

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[4] Bradsher, Keith, "China Far Outpaces US in Building Cleaner Coal-Fired Plants," *The New York Times*, May 11, 2009.

[5] According to figures compiled by the Cleantech Group and Deloitte. This figure is actually down from $8.5 billion in 2008. See "Clean technology venture investment totaled $5.6 billion in 2009 despite non-binding climate change accord in Copenhagen," Cleantech Group and Deloitte, press release; http://cleantech.com/about/pressreleases/2090106.cfm.

The State of the Network

Apart from failing to bring renewable energy on line, the United States has not kept pace with other countries or indeed, by most accounts, essential needs in the critical task of modernizing and upgrading our electricity network to ensure resilience. This includes ordinary upgrades and extensions of capacity as well as the deployment, let alone invention, of new technology to improve system performance.

At various times, Congress has stepped in to address problems with the electricity network. In the 1930s, as discussed below, the federal government took the lead in pressing for rural electrification. After the 1965 blackout, Congress commissioned the voluntary North American Energy Reliability Council (NERC) in 1968 and, following a series of Congressional hearings on blackouts including the New York blackout of 1967, the industry created the Electric Power Research Institute (EPRI) in 1973 as a joint research and development consortium. Since then, EPRI has been widely credited with doing excellent work.

Notwithstanding these efforts, however, the network has not kept pace with demand. Just how starved the network has been for investment emerges from data collected by the Edison Electric Institute since 1978 and NERC since 1999 on transmission and distribution capacity. Using this data, industry analyst Eric Hirst has calculated that transmission capacity, after peaking in 1982, underwent a steady *declin*e over the next two decades of about 1.6% per year. Thus capacity, in 2002 when he concluded his study, was almost *30% lower* when normalized for load than at the outset of the 1980s.

Transmission capacity is indeed growing at only one-quarter of the rate of generation. The starving of transmission and distribution capacity has led others to use terms like “bare bones,” “inadequate,” and “dangerous” to describe the condition of the nation’s threadbare grid. Former CIA Director James Woolsey has sounded the alarm regarding the poor security of the network. In everything from its capacity to its switching to its level of security, the grid conforms with Former Energy Secretary Bill Richardson’s description of it as a “third world grid.”

Investments in this year’s American Reinvestment and Recovery Act in smart-grid technology, storage technology, and other measures to upgrade and modernize the network, though substantial, provide only a small fraction of the money that will be required to make up for years of neglect.

The deficiency of the network is highlighted by comparison with the communications network. In recent years, 3G infrastructure alone has been the recipient of $800 billion in investment, a vast multiple of the approximately $7 billion a year (not including the recent U.S. government stimulus bill) that is, on average, being invested in the electricity network.[6]

In short, the platform on which clean energy depends has been starved for funding and is now in dire need of upgrades.

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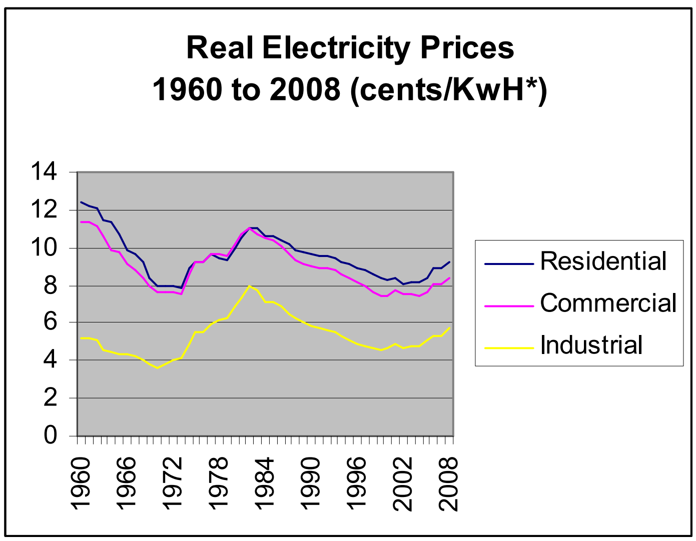
[6] American Society of Civil Engineers, *Report Card for America’s Infrastructure, 2009*; http://infrastructurereportcard.org/fact-sheet/energy.

The Price of Electricity

Using current exchange rates, the U.S. now enjoys the lowest cost electricity of all of the industrial powers. Given the dependency of international comparisons on volatile exchange rates, however, a more valid comparison is probably what has happened to electricity prices in the U.S. over time. The general trend is that over the last half century electricity has declined modestly in price.

As Figure III-6 shows, today residential and commercial power are less expensive in real terms than in 1960 while industrial power is about the same. Broadly speaking electricity prices fell sharply in the 1960s, rose sharply in the 1970s through 1983, declined gradually over the next 18 years to about 2001, and then began to rise up until today. Notably, during the first four to five years of partial deregulation after 1996 they declined and then began to rise after 2001. In some instances, prices were capped after deregulation.

Figure III-6



*in chained 2000 U.S. $
Source: Energy Information Agency

While this may seem like a solid performance, it must be placed in context. Over the same period, some commodities have risen in price but others have seen their price collapse, reflecting major forward strides in efficiency and productivity.

As a general matter, long and sustained price declines occur in response to technological breakthroughs and major investment that increases supply. This is the story, for example, with the stark declines in the price of transmitting data since the Judge Green decision to break up the AT&T telephone monopoly in 1984 and the collapse of the price of stock trading.

On the other hand, sustained price rises generally result from increasing demand relative to supply as well as lack of increases in productivity from technology. Physical commodities in limited supply, such as oil and natural gas, can benefit from improvements in technology, such as offshore drilling capability, but their prices also reflect their limited supply. Physical oil supplies as well as coal supplies are theoretically fixed, as all three are the residue of organic matter crushed under pressure over a period of many years. New discoveries, however, have meant that, in practical terms, known oil and gas reserves have fluctuated. The more telling determinants, therefore, are cartel decisions, demand, which fluctuates in response to prices and the global economy, and market manipulation, if any.

Electricity is an interesting commodity in that it is entirely dependent on technology to produce and convey—like communications—but also, frequently, in that it requires energy as a feedstock. To the extent the input is a finite resource such as natural gas or coal, therefore, electricity prices may depend on the feedstock. Alternatively, they may depend principally, as in the case of nuclear and solar electricity, on the price of the plant and equipment needed to produce them. In this case, technology breakthroughs could, conceivably, dramatically lower their cost.

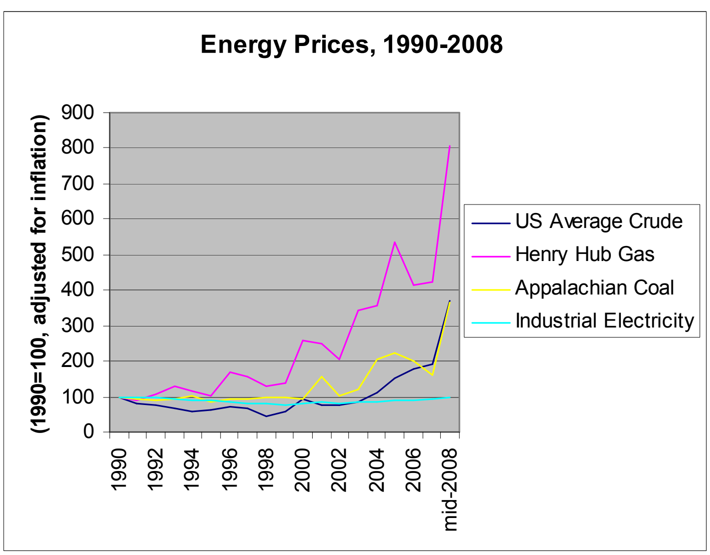
The issue is complicated, however, by the rigidity of the industry imposed by its high levels of fixed investment and, in particular, its heavy regulation.

Investment decisions once made are hard to reverse, and wrong decisions can be very expensive. Thus large capital investments in new technologies can lead to higher rates if costs are mis-estimated, as indeed happened during the nuclear buildout of the 1970s.

A fair assessment of the long term cost of electricity in the U.S. suggests that regulators and industry have succeeded in keeping price increases moderate (albeit painful at some times and places) but have not managed to dramatically lower costs, as has occurred in industries that have benefited from productivity increases through technology breakthroughs (such as telecom services).

Figure III-7 shows commercial electricity prices relative to the prices of several other commodities: Oil, natural gas, coal, computer bandwidth, and the cost of executing a stock trade.

Figure III-7



Source: Energy Information Agency

It is apparent that electricity prices have stayed flat though other energy prices have soared, including the costs of key fuels used to make electricity. It could be that electricity has grown more efficient. But electricity prices have risen far more rapidly than have computer bandwidth or stock transactions, both of which have plummeted in price, delivering far more value per dollar spent than two decades ago. Understanding why prices rise and fall is a complex undertaking that I will not attempt here. It is sufficient to suggest that electricity prices did not rise as rapidly as other energy prices but rose far more rapidly than some other commodities. The question of whether one should be satisfied with this performance should be phrased, therefore, as whether one is satisfied with the performance given what might have been achieved.

Clearly, had the electricity industry experienced extraordinary breakthroughs—as some anticipated would flow from nuclear power or fusion power—it would have declined in price. Similarly, had renewable power met expectations then energy prices might have dropped. The chaining of electricity production to the price of other energy commodities with other demand, notably coal and natural gas, however, has prevented prices from disruptive declines.

Finally, the power industry has made only modest strides in promoting efficiency and has not introduced an important new product or product variant in decades, continuing to market electricity as a single, pure commodity.

In other industries, it has proven beneficial in recent years to tailor or 'version' products to suit the preferences of different classes of customers and to empower customers to customize their own product attributes. That has not occurred in the power industry, even to the extent of widespread offerings of pricing plan alternatives.

Still less has the power industry introduced new products and services that one might envision, such as guaranteed power, power storage, power monitoring devices, home automation, or direct low-voltage current to service the plethora of low-voltage, direct current devices, such as cell phones, that now fill the home.

Given the potential of Electricity 2.0 but the slow pace of change, the question arises: What is preventing America, its utilities, its energy consumers, and the American people from realizing the renewable revolution and obtaining the benefits of Electricity 2.0?

IV. Roadblocks to the Renewable Revolution

The tremendous potential benefits from clean electricity and Electricity 2.0, but America's slow progress in achieving them, suggest that something is blocking the renewable energy revolution. Some of the roadblocks, such as the poor physical state of the grid, are plainly visible.

But others are more subtle, as is the case with biased decision making against new technologies, an institutional reluctance to empower consumers, and the withering of the culture of innovation as R&D spending has dwindled.

In this section I will discuss why these problems exist. I begin by describing them.

Problems with the Network

The nation's grid or electricity network was built during the 19th and 20th centuries and remains, in many cases, antiquated, undercapitalized, and outdated. It has been compared to the system of two-lane roads, crammed to capacity with cars and trucks prior to construction of America's highways.

However, in reality, it is even worse, insofar as the two-lane roads lack on-off ramps, do not reach substantial swaths of the country, and are organized in a hub-and-spoke pattern emanating from the power plants of a half-century ago.

As noted by Former Vice President Al Gore, the poor state of the grid is a particular problem for wind energy producers. Since cities are rarely located where the wind blows hardest, the effective harvest of wind energy often requires grid capacity to connect the wind with people.

And that capacity is missing.

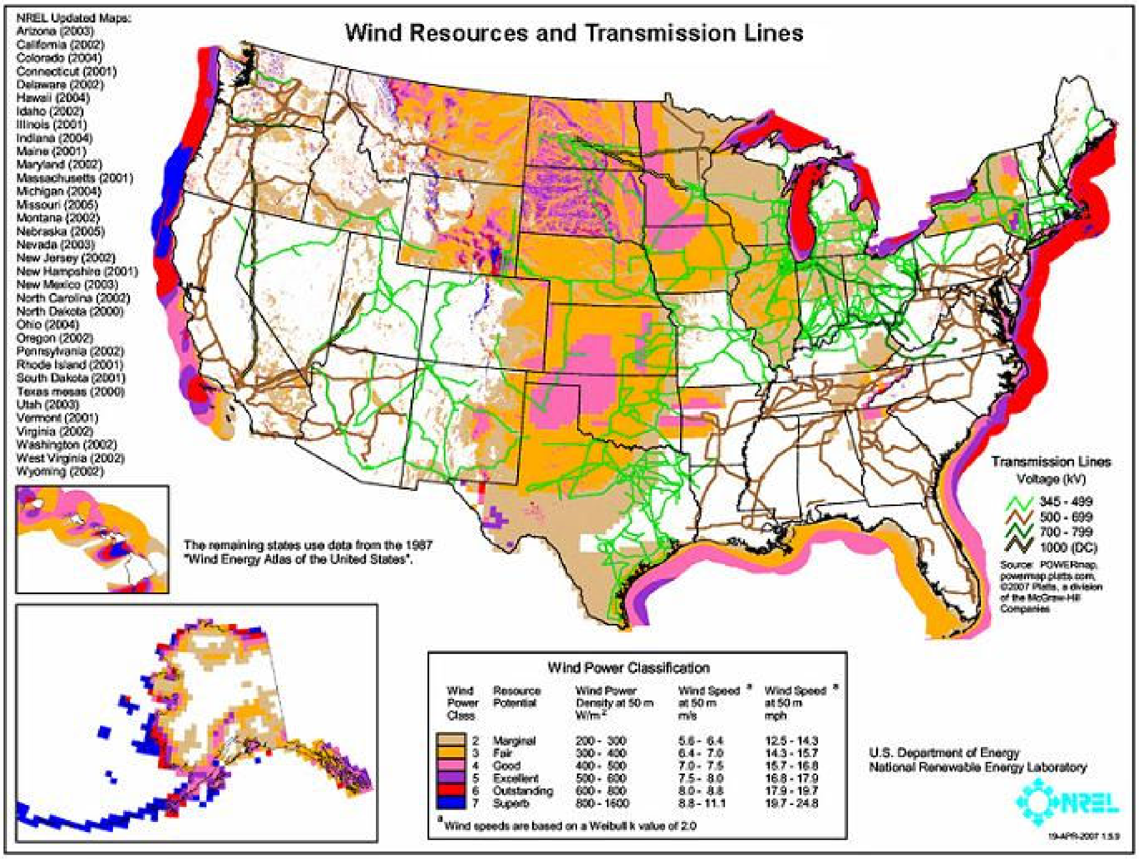
The physical network suffers from the problems outlined below.

First, it lacks *reach*. While the grid now services the vast majority of load in the U.S., it lacks reach on the supply end to many potential sources of electricity.

The Midwest has been called the Saudi Arabia of wind. As Figure IV-1 (next page) shows, wind rolls down the middle of North America from the Dakotas through Nebraska, Kansas, and the Texas Panhandle on down to Mexico. Wind turbines placed in the path of this wind turn day in day out, generating large quantities of electricity.

However, for the most part the lines to move electricity thus generated to where it is needed in American cities do not exist. Accordingly, only a small number of wind farms have been built to date relative to what analysts say the region could support. (The other main wind resources in the U.S. lie over the Great Lakes and off the Atlantic and Pacific coasts.)

Figure IV-1



Source: National Renewable Energy Laboratory

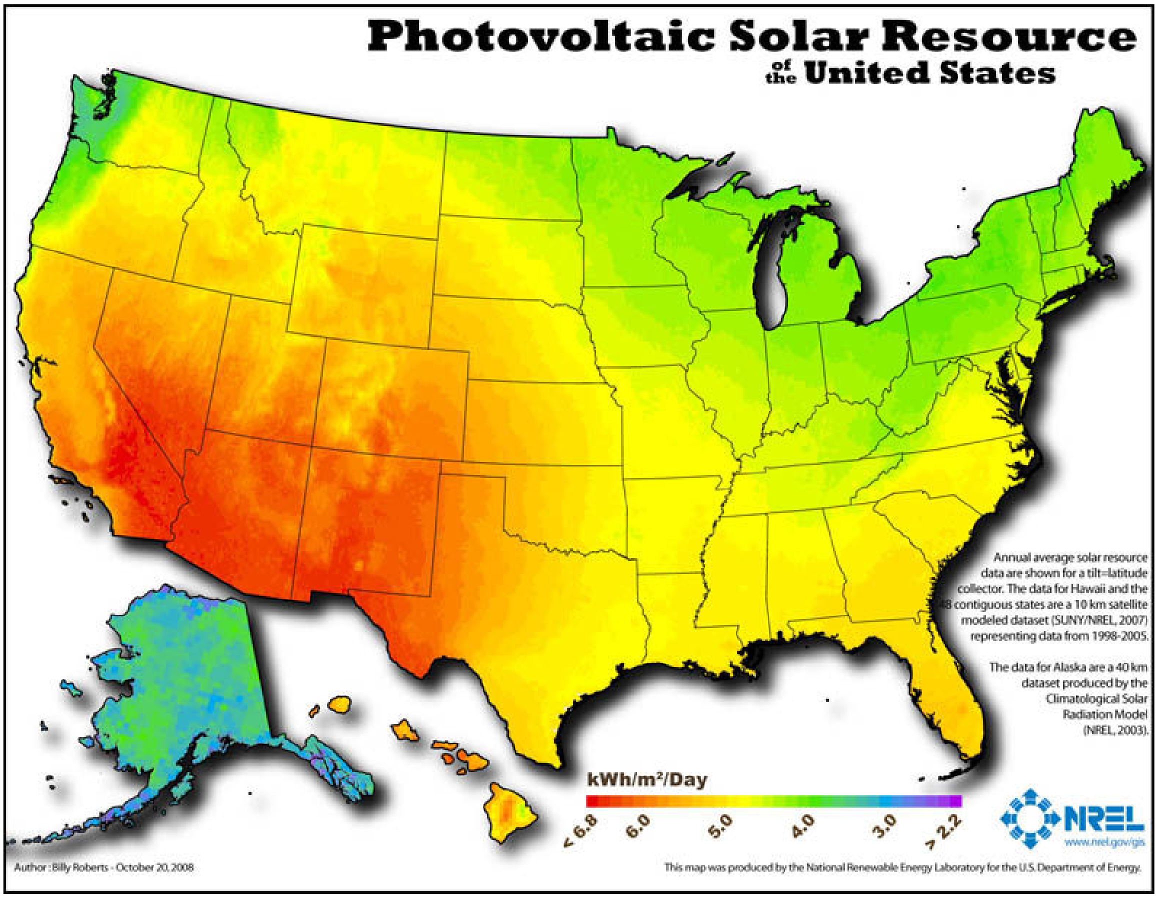
As Figure IV-1 also shows, solar power is strongest in the Southwest part of the country. Comparing this map with Figure IV-2 (next page) shows that lines to connect the sun-drenched Southwest to power-hungry California also do not exist. This absence of connectivity lines is a major barrier to the development of utility scale renewable resources.

A lack of reach in the network—namely adequate wires linking up different parts of the country—makes moving electricity difficult and expensive and literally makes it impossible to connect a new wind farm or solar thermal facility.

Second, the network lacks *capacity*. Even where lines exist they are often undersized. The grid has been compared to the U.S. network of roads in the 1950s prior to the construction of interstate highways, when cars, trucks, and horses moved about the country on two-lane roads.

The absence of network capacity drastically curtails trade in power and its free flow from where it can be cheaply produced to where it is needed, leading to the current balkanized system. Were capacity greater, electricity would more closely resemble other commodities—produced where cheapest and consumed where dearest.

Figure IV-2



Source: National Renewable Energy Laboratory

One potential solution to the problem of congestion is the creation of a national backbone of electron super highways, as NDN has long proposed. For the system to work at peak efficiency, however, these would need to feed in to a vastly upgraded local network. Another answer is the construction of private long-distance lines and, recognizing the need, some such lines have been built.

The third major deficiency of the grid is *inadequate intelligence*. The grid lacks automation due to limited information transfer and antiquated switching and grid operators lack state-of-the-art tools and software to manage the flow of power. While the grid naturally has many safety features built in and operators have many tools at their disposal, too often they must intervene manually and reroute power by picking up the phone. Lack of computing power and software, incompatible software, poor or non-existent standards, and older and antiquated equipment remain pervasive, encompassing everything from old relays and switches at central locations to analog meters at customers' residences.

Fourth, the grid lacks *security*. The simple mechanisms and controls it has in place amount to almost no security at all and, therefore, the main security barriers are physical and informational: The presence of fences, locks, and guards around important switches and ignorance of which switches and substations are the most critical.

The fifth major deficiency of the grid is *poor network design*. In older parts of the country, power networks developed as self-contained units that were later stitched together. Even in newer installations, networks tend to branch out like trees from a central office in series and, therefore, when power is cut have limited self-healing ability. Frequently there is no redundancy, leading to the kinds of lengthy outages that have become a regular occurrence in many parts of the country. The exposure of power lines to the elements in many areas leads to frequent interruptions from weather, squirrels, trees, plants, and other hazards.

If the grid were being built from scratch today, engineers would undoubtedly build far more intelligence and redundancy into the network to permit portions of it to continue and redundant lines to take over in the event of an outage. And they would protect it from the elements.

Finally, the network lacks *storage capability*. This is often attributed to an inherent technical difficulty in storing electricity, but it is just as attributable to a lack of investment in new, distributed storage technologies.

While centralized storage on a scale comparable to centralized generation is technically challenging, wide area distributed storage is feasible today. Just as the computer network distributes storage widely across the network in everything from cell phone memory to on-board RAM to computer hard drives to office servers to data warehouses to server farms, the electricity network could efficiently store electricity in devices, customers' homes, substations, and elsewhere.

Batteries are already widely used in small devices, but no intelligence maximizes their value to the network and a gap exists in the storage spectrum between very small-scale storage and very large-scale utility storage. A middle class of storage is missing. Few homes have battery storage or generating capacity. Yet the price of storage for the home would be less than homeowners spend on a new refrigerator. The price of a gasoline backup generator is less than a low-end laptop computer, but few people make such an investment.

For the time being, the absence of storage capability (apart from a small number of large hydro storage facilities) reduces network flexibility and resilience.

In short, the grid lacks reach, capacity, intelligence, security, state-of-the-art network design, goods standards, and storage capability. These problems both repel clean, renewable energy from the network and, themselves, exemplify the slow uptake of new technology.

Other Roadblocks to the Renewable Revolution

Besides the physical state of the grid, a variety of other roadblocks are preventing the more rapid deployment of clean technology.

<u>Flawed estimates of cost</u>. While most decisions about investments and power purchases are theoretically based on the desire to minimize cost, how cost is determined is fraught with problems.

Perhaps the biggest miscalculation in the modern history of electricity has been the failure to correctly anticipate the cost of nuclear plants. Most of the cost of a nuclear plant lies in its construction—as opposed to the cost of nuclear fuel. The problem of estimating cost is therefore primarily a problem of estimating construction costs. However, given the substantial safety costs involved in managing the nuclear production of electricity, devising a robust spec for a nuclear plant and understanding its cost of construction is a complex process. In the 1970s, the industry collectively failed to anticipate costs. Substantial cost overruns and a need for more safeguards than originally planned led to large cost increases for consumers in the 1970s as a result of nuclear power.

Second, utilities have tended to favor traditional baseload power from coal and nuclear plants over distributed power, demand response, energy efficiency programs, and other strategies to balance production of electricity and load. In the case of energy efficiency and many demand response technologies, obviously, lowering the quantity of electricity sold lowers the revenue of the utility under the rate-based system of return. (Decoupling sales and profits, enacted in several states including California, Idaho, and Maryland, is designed to address this bias (Box IV-A).[7]

Box IV-A
Energy Efficiency in California

Electricity 2.0, by providing network participants with better information about electricity usage, has the potential to dramatically improve energy efficiency. An example of the potentially transformative impact of smart electricity use is the success of energy efficiency standards in California.

A year after the oil embargo of 1973, Art Rosenfeld, then heading a particle physics lab at the Lawrence Berkeley National Laboratory, switched to the new field of energy efficiency. Building on work at a new center on energy efficiency he founded, he led efforts to promote energy efficiency in California, gaining fame with his initiative to improve the efficiency of refrigerators, which at the time consumed large amounts of electricity.

Prior to Rosenfeld's initiative to improve energy efficiency for refrigerators, skeptics claimed it could not be done cost effectively and might actually bankrupt the refrigeration industry. Instead, the industry has flourished, thanks in part to their lower cost of operation. The savings from improved efficiency in refrigerators alone is equal to 65%, by some estimates, of the value of the nation's nuclear power capacity. Savings from improved energy efficiency in refrigerators exceeds the electricity generated from conventional hydropower and renewable energy combined.

Through the refrigerator initiative and others, California has dramatically improved energy efficiency relative to other states, permitting it to grow dramatically in population without having to increase its electricity capacity.

Similarly, investments in distributed power, such as solar energy, made by customers or third party providers, such as Sun Edison or Sun Power, represent a direct loss in sales volume to utilities and, in effect, a loss of market share. While utilities generally make it possible to install solar power, it is rarely an easy process and customers face difficulty in selling excess power to others or even back to the utility.

[7] Not all states that have enacted decoupling have maintained it. Maine, New York, and Washington, after trying decoupling, have discontinued it. Currently, Vermont has a regime similar to decoupling in place, and some states are considering it, notably Oregon.

Skewing many cost-benefit calculations to the disadvantage of distributed power is that the social savings from distributed generation in the form of reduced demand on the grid are not currently captured by the producer of distributed power. When a homeowner places solar on his or her rooftop, the homeowner frees up grid capacity for the utility, but that value does not currently accrue to the homeowner. And the utility—again because of the rate-based system of return—may not benefit in economic terms either, because if that portion of the grid is not yet paid for a decline in its use will prevent the utility from recovering its stranded costs.

<u>Confused and conflicting standards</u>. Complex standards for connecting to and using the grid further repel those who might wish to install capacity. Wind farm operators report bias against hooking-up capacity while those wishing to connect something as simple as solar panels to their homes face a bewildering array of requirements that differ by state. Solar companies estimate that simply agreeing on a common national standard for hookups would sharply accelerate the deployment of solar power. Similarly, common standards for 'net metering' or selling power back to the grid or, alternatively, selling power to other users across the grid would accelerate the deployment of distributed generation. Yet net metering, even where it exists, generally allows consumers to earn only the 'avoided cost' of power, not the real value of the power they supply (Box IV-B).

Box IV-B
Watching the Meter Run Backwards

If a home's solar panels or wind turbines generate more power than the house consumes, by the laws of physics the power will actually run back into the grid, causing many meters to run backwards. Watching the meter run backwards provides tangible proof of consumer empowerment. In most cases, people receive the "avoided cost" of this power in the form of a reduction in their utility bill. In Germany and some other European countries, they actually receive a price higher than the average cost of solar through a "feed in tariff." Many states here in America, however, do not allow net metering, and there is no national net metering requirement.

Electricity 2.0 will allow people to sell power back to the utility and could even allow groups of people or large producers to bid into the wholesale market. Watching the meter run backwards or profiting from producing your own electricity is one way that the average American will be able to participate in Electricity 2.0.

The case study examples, discussed in the sidebar Boxes that appear below, discuss instances of flawed decision making by utilities leading to the investment in technologies that ultimately increased rather than decreased the price of electricity while choosing non-renewable sources of power.

<u>Dwindling R&D</u>. A lack of research and development within the utility sector is a further roadblock to the industry's advance. The National Science Foundation collects data on R&D in the economy as a whole and FERC has collected data on R&D spending in the electricity industry since the early 1990s. The data show that R&D spending in the electricity industry, which was always precipitously low, has declined sharply since the early 1990s.

The NSF reports that in 1995 and 1996, the only years for which it has utility data available, the percentage of sales of utilities (gas, electric, and water) was 0.2% and 0.3%, respectively, in contrast to a rate of 10.1% and 10.2% in business services, 6.7% and 6.2% in electrical equipment, and 10.1% and 10.5% in drugs and medicines. The level of R&D among utilities was the lowest of any sector, only half that of the next lowest sector, food and tobacco.

Analyzing FERC data, two researchers have found that during the 1990s R&D shrank alarmingly from its already low levels. From a high of $741 million (in 2000 dollars) in 1993—itself extraordinary for an industry with hundreds of billions in sales—R&D expenditure declined to $193 million in 2000, a drop of nearly 74%. This drop took place in all of the components of industry R&D, that within companies, that performed by General Electric (the equipment company, the largest performer of R&D in the sector), and that by EPRI (the industry consortium formed after the U.S. Congress held hearings on low R&D spending after the 1965 New York City blackout).

While EPRI has earned high marks as an industry consortium, utilities cut its funding by 71% as they cut back generally on R&D efforts. The only component of overall energy R&D to stay at least flat was that of the Department of Energy, which declined 3% over the period. As an example of the precipitous decline at companies, Duke Energy halved its R&D from $18 million to $9 million while Southern California Edison, which had spent 70 million on R&D in 1994, spent only $1 million in 2000, a decline of almost 99%.

In short, the poor state of the network and decision-making bias against new technology comprise two very large and visible roadblocks to Electricity 2.0 and the renewable energy revolution. But the poor state of the network begs the questions: Why has the network so deteriorated and why is the bias permitted to exist?

To understand the deeper, structural causes both of the poor state of the network and the excruciatingly slow pace of implementation of renewables, one has to look deeper into the history of Electricity 1.0 and the structure it has created.

V. Electricity 1.0: The History of the Electricity Network

While the problems of the grid and electricity sector are clear enough, why they exist and how to fix them are more opaque. What must be done to solve the problems is closely related to the history of the network.

Static electricity and magnets were known to the Greeks, but the ancients never made use of electrical power. It took Ben Franklin flying his kite to link the static variety to lightening visible in the air while the key theoretical work on electromagnetic fields by Faraday, Ohm, Volta, and Ampere took place in the 18th Century.

The history of commercial electricity (Box V-A, next page) dates from Thomas Edison's demonstration of a practical carbon filament light bulb in 1879.

The Go Go Years

Edison opened his first test plant in London in 1882, and later that year he fired up his first commercial generator on Pearl Street in lower Manhattan. Perfecting fuses, constant voltage, parallel circuits, and other back-end ingredients of reliable power, as well as front-end products like the light bulb and fan, Edison demonstrated to the world the commercial viability of electric power.

For the next quarter-century, advances in the industry would be fast and furious. This was the golden age of Electricity 1.0, when engineers and tinkerers like Edison (known as the Wizard of Menlo Park for his invention of the phonograph) and his employee-turned-competitor the eccentric genius Nikolas Tesla, financed by investors like JP Morgan and Cornelius Vanderbilt, created the modern electricity system together with most of the devices it would power.

Edison favored direct current or DC, the form of electricity that occurs in nature, in which electrons flow in one direction from a place of higher to lower potential, arguing it was the safest way to transmit current.

Because direct current once produced could, at the time, not easily be altered in voltage, his dynamos produced power at different voltages for different devices, like light bulbs or machinery, and sent it out along different lines to different locations. Relatively high losses on the 110 volt lines Edison chose for incandescent lamps meant that power plants had to be within a mile or so of the load. Early DC networks were thus self-contained and decentralized due to the limited range of DC power and the proliferation of providers.

Not long after Edison launched his service, a young Serbian engineer hired in Edison's Paris office perfected a different way of transmitting power (first tried by Faraday) called Alternating Current. With AC power, energy moves one way and then back again many times a second. Tesla developed multi-phase alternating current that sent repeated waves out and back again in staggered fashion to increase energy throughput.

Box V-A
Timeline of the Modern Electricity Industry

1879
Edison introduces first practical carbon filament light bulb.

1882
Edison open Pearl Street Plant in Lower Manhattan offering DC power

1892
Westinghouse and Tesla light Chicago Columbia Exhibition with AC power

1893
Niagara Falls contract awarded to Westinghouse; power flows three years later

1903
Samuel Insull commissions 5 megawatt steam-driven turbine for generating power

1905
Wisconsin, under progressive Gov. Robert La Follete, is first state to regulate electric power at state level

1907
New York, governed by Charles Evan Hughes, follows suit

1931
Hoover Dam commissioned

1933
Tennessee Value Authority created

1935
Rural Electrification Administration created

1935
Public Utility Holding Company Act of 1935 (PUHCA) passed

1937
Bonneville Power created

1965
New York City's "good" blackout characterized by cooperation

1973
EPRI created following Senate Hearings on R&D shortfall in industry

1977
New York City's "bad" blackout characterized by looting and crime

1978
PURPA passed

1979
Three Mile Island accident

1992
EPACT

1996
FERC Orders 888 and 889

1999
FERC Order 2000

2000-2001
California Energy Crisis

2003
Northeast Blackout

2005
Energy Policy Act of 2005; Public Utility Holding Company Act of 2005

After failing to convince Edison that AC was superior to DC or get a raise for his discovery, Tesla left Edison's employ. Working as a laborer to raise capital, starting his own company, and then partnering with George Westinghouse, an astute acquirer of patents and accomplished inventor in his own right, Tesla campaigned for AC power. If Edison personified the tireless American tinkerer, Tesla personified the eccentric genius, wowing crowds at expositions with his Tesla coil that shot plumes of electricity high into the air. Fascinated with electric radiation, he experimented with higher frequencies that led him to invent radio[8] and experiment with X-rays.

He invented the amplifier, the spark plug, a radio-controlled boat, a wireless telegraph, and an early form of radar. He proved, defying skeptics, that electricity could be transmitted through the Earth, however, he fell short in his greatest goal of transmitting large volumes of electricity through the air. After transmitting huge arcs of electricity long distances in Colorado Springs, with money from JP Morgan he built a huge tower in Wardenclyffe, Long Island, that he told Morgan was for wireless radio broadcasts to Europe but was also to send electricity through the air—or possibly the Earth, for deep below the tower were iron coils that could send waves through the Earth. When Morgan cut him off, Tesla took out a mortgage from the owner of the Waldorf Astoria, George C. Boldt.

Unable to keep up payments, he had to turn the property over to Boldt who demolished this monument to genius. Other partially completed projects included a theory of gravity, a flying device based on electrical fields, and the Peace Ray, as the press described it, a powerful electrical weapon that Tesla claimed could stop hundreds of planes in the air and cause armies to drop in the field.

Because of this work, the U.S. government seized all of his papers upon his death. Tesla believed it possible to draw energy from the Earth's movement through space, from the spin of electrons, and from other sources in the "ether," and he did succeed in sufficiently charging earth to illuminate a filament. (For an account of one of Tesla's most intriguing if apocryphal inventions, a shoebox-sized power pack that drew AC current from the air that Tesla supposedly used to drive a Packard car 90 MPH in the 1930s, see Chapter VII.)

The War of the Currents

Edison's DC current had several advantages over Westinghouse and Tesla's AC. It could power a motor, something AC could not do at first. It was safer; AC could cause fibrillation of the heart. And DC power could flow directly into batteries.

AC, on the other hand, could be readily stepped up and down to accommodate different voltage devices. (Tesla stepped it up to 1 million volts or more to create the plumes of sparks.) Because stepping the voltage up reduced power loss, it could travel long distances.[9] AC required only one wire to each customer since voltage could be adjusted onsite for different devices.

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[8] While the patent office at one point transferred his radio patent to Marconi, who then won a Nobel Prize, the U.S. Supreme Court returned the radio patent to Tesla after his death.

[9] Electric power is the product of voltage and current, but line loss is proportional to current only—so a low current at a high voltage suffers less loss than a high current at a low voltage of equivalent power.

When Tesla solved the motor problem by inventing the induction motor, AC gained a decisive advantage in what became known as the war of the currents. The end came when Edison and Westinghouse competed to supply technology for a generator at Niagara Falls. A blue ribbon panel that included Lord Kelvin and JP Morgan chose AC as the winner, and a few years later the Westinghouse generator began supplying power to Buffalo 30 miles away. With the Niagara contract, AC power won the war of the currents. An additional benefit of AC, stemming from its ability to step it up and down, was that it could be networked from site to site.

The networked AC model swept across the nation (though DC power survived in cities and in uses such as elevators for many years.) This first period of innovation and expansion of electricity lasted up to the Panic of 1907, which brought an end to exuberance and was also the year, coincidentally, in which state regulation of utilities took hold in New York.

Municipal Controls

During the early years of direct current, rival producers of power had literally run electric wires from dynamos to customers, creating a complex and dangerous web of crisscrossing wires, visible in turn-of-the-century photographs. After snowstorms caused fires, and as a reaction against so many wires and too many crews digging up streets, by the early 1900s many municipalities began to limit the erection of wires and designate one company as the monopoly provider. Industrialists supported monopolies as a way to check freewheeling competition which undercut profits. With the template of regulating ‘natural monopolies’ in water and gas fresh in hand—a process with ample opportunities for politicians to benefit through insider deals—many cities chose to license a monopoly while a few took over the provision of electricity for themselves.

City licensed monopolies, or, alternatively, municipal ownership, soon became the dominant models of electricity provision. However, they had several limitations. First, alternating current made it feasible to move electricity longer distances crossing multiple municipalities. Producers thus faced different rules across their network. Second, high prices and dissatisfaction with corrupt city officials gave reformers a reason to try to remove regulatory authority from local political machines. Indeed, concern about electricity trusts fed into a broader movement of populism sweeping across the United States.

Populism had its roots in the granger movement among farmers to rein in the power of railroads. Agitation by farmers threatened or ruined by predatory railroad pricing led in 1887 to the creation of the Interstate Commerce Commission to regulate railroad pricing. The ICC satisfied the grangers and also JP Morgan who declared that while organizing trusts was his favorite way to consolidate an industry for profit, government regulation was the next best option.

By the turn of the century, the populist movement had won over two parties, the eponymous Populist party and, after William Jennings Bryan’s famous 1896 “Cross of Gold” speech, the Democratic Party.[10] It had broadened its aims to include not only measures to aid farmers, such as free silver coinage, but also checks on the power of trusts and, in cities, a halt to the waste and corruption of political machines. As part of its goal of taking power away from local party

[10]Despite winning his party’s nomination for President, Bryan lost the 1896 election to William McKinley.

machines and vesting it in professional managers, public authorities, and unelected boards, progressives promoted the idea of creating state regulatory bodies to regulate utilities. Once more utilities supported the idea as they viewed one state regulator as friendlier (and perhaps easier to capture) than multiple municipalities.

State Regulation and the Cost-Base Rate-Base System of Rates

The first states to regulate electricity at the state level were the progressive hotbeds of Wisconsin and New York. In 1905, Wisconsin, under the famous progressive governor, Robert La Follette became the first state to regulate power. Two years later, New York, governed by another famous progressive, Charles Evans Hughes, adopted a similar measure.

Incorporating the economic ideas of Richard T. Ely—the premier economist of the Progressive movement who taught at the University of Wisconsin and then Johns Hopkins and whose students included Woodrow Wilson—and modeled on railroad regulation that had not only helped farmers but, to the satisfaction of Wall Street, turned the railroads into predictable profit machines, the regimes installed in Wisconsin and New York gave the state the power to set rates. In exchange, however, the utilities won freedom from competition and a guaranteed rate of return on approved investments. Facing no competition and enjoying government guaranteed rates of return, the utilities found it easy to borrow money.

Thus, after the Panic of 1907 subsided, utilities began to expand and consolidate using their power to raise money. Their stocks and bonds, meanwhile, became a preferred investment vehicle for risk-averse widows and orphans. During the 1920s, investors created holding companies to own multiple utilities until a handful of investors came to control the bulk of national power generation and distribution. Utility holding companies were a financier's dream because they let investors use the stable cash flow from a regulated business to finance other ventures. However, when the market turned against speculation in response to the 1929 Crash, one after another utility that had loaded up on debt went under.

In 1935, as one of its many financial reforms, the Franklin Roosevelt Administration secured passage of the Public Utility Holding Act, outlawing holding companies, barring utilities from owning unregulated companies, and preventing other companies from investing in utilities. As part of its drive to end rural poverty, the Roosevelt Administration also passed laws to authorize the Tennessee Valley Authority and otherwise extend electricity service to rural areas. As in so many industries, during the Depression and then during the war years, the federal government entered the energy industry in a large way, financing rural electrification and the exploitation of hydro resources in the Northwest, in Tennessee, and at Hoover Dam.

The end of World War II ushered in a period of steady growth in electricity whereby supply kept up with and at times surpassed demand. The rate-base system of state regulation as modified by federal legislation by and large worked well through the 1960s. Utilities made steady investments in capacity. Low fuel prices and a large supply of hydroelectric power in some regions kept rates under control. Nuclear power began to come online at a high initial cost but with the promise—as famously stated by Lewis Strauss, President Eisenhower's chairman of the

Atomic Energy Commission—that it would make electricity so cheap it would become unmetered.

A warning that the industry might be under-investing in R&D appeared in the form of the 1965 and 1967 blackouts. The latter prompted the industry to create EPRI to conduct join industry research. Nonetheless, utilities had performed their job so steadily and unobtrusively for so many years that it took another New York City blackout in 1977 to shine a light, so to speak, on the systems' growing problems.

By the mid-1970s, the industry had run out of hydro opportunities and faced increasing opposition to nuclear plants, driving their cost up and raising questions about future energy supplies. The oil crisis in the 1970s focused attention on energy issues generally, leading to the creation of the Department of Energy in 1977. Throughout the 1970s prices of electricity for industrial, commercial, and residential customers rose steadily. In 1978, to stimulate the development of alternative energy Congress passed the Public Utility Regulatory Policy Act (PURPA), requiring utilities to buy power from independent power producers at prices set by regulators. Then, following a series of cost overruns and the 1979Three Mile Island accident, the price of new nuclear capacity skyrocketed and most nuclear projects got cancelled. During the 1980s, rising environmental costs raised the price of coal-fired power. Thus began a period of steadily rising rates that by the early 1990s had stimulated increasingly strident calls for reform.

Partial Deregulation

The immediate precursor to partial deregulation was the drop in prices for independently sourced power, including co-generation in the early 1990s relative to regulated power. Regulated power had increased in price for a variety of reasons, including a rate-base that had grown in size due to the exploding cost of nuclear power and, indeed, any new capacity. Industrial consumers realized they could produce power for less on their own or, where permitted, buy it from independent producers. In 1992, Congress passed EPACT, empowering FERC to open up the transmission grid to independent producers. The system seemed analogous to that among a variety of other industries prior to regulation, where prices fell after deregulation. Industries that preceded or accompanied electricity in their deregulation include airlines (1978), financial services (1975 and onward), and telecom (1996). Other countries were also undertaking electricity reform, notably England (and Wales), Argentina, and New Zealand, often in combination with privatizing state-owned utilities.

In 1996, FERC issued Order 888, which effectively launched partial deregulation and further opened the grid to independent power producers, prompting some states to deregulate their industries to protect their regulated utilities from low-cost producers in adjacent states.

Within three years, about 20 states chose to deregulate; however, that number has remained roughly frozen. The general idea behind most deregulatory efforts was that the local distribution of power is a natural monopoly but the generation of power, the long-distance transmission of power, and the retail sale of power are amenable to competition.

Thus many states forced utilities to sell off or transfer some or all of their generation capacity to a new tier of unregulated generators.

In 1999, FERC issued Order 2000, which led to the creation of Regional Transmission Organizations or RTOs, regional pools for balancing load, some of which, like the country's largest—the Pennsylvania, New Jersey, and Maryland (or PJM) interconnection span multiple states.

Auction markets were created in partially deregulated regions to allow generators to sell power to distributors. Since states varied in how they deregulated, however, the result was a mix of different regimes, some of which worked but some of which failed disastrously. In fact, most states and regions chose not to deregulate at all. FERC efforts to encourage deregulation met substantial opposition in some parts of the country and, as a result, deregulation was implemented sparingly. Box V-B shows states that are regulated and unregulated.

Box V-B
State Regulatory Regimes

Regulated	*Unregulated*
Alabama, Alaska, Arizona, Arkansas, Colorado, Florida, Georgia, Hawaii, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Minnesota, Mississippi, Missouri, Nebraska, New Mexico, Nevada, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, South Carolina, South Dakota, Tennessee, Utah, Vermont, Virginia, Washington, West Virginia, Wisconsin, Wyoming (36)	California, Connecticut, District of Columbia, Delaware, Maryland, Massachusetts, Maine, Michigan, New Hampshire, New York, New Jersey, Pennsylvania, Montana, Rhode Island, Texas (15)

The California Energy Crisis

While many observers consider partial deregulation largely successful, the process was bumpy and is certainly unfinished. Some condemn it entirely. The most celebrated failure was the first round of deregulation in California that led to a full-blown crisis and, despite the recovery of the California electricity industry, is still invoked to condemn deregulation as a whole.

The crux of the California energy crisis in late 2000 and early 2001 was that under the deregulation law passed by the state legislature in response to heavy lobbying, utilities, forced to divest their own generating capacity to independent power producers and denied the ability to enter into long-term contracts with those producers, had to buy power on the open market but face caps on what they could charge customers. When prices on the spot market soared at the end of 2000—due to drought that had reduced hydropower available from nearby states in combination with soaring gas prices and, it was later revealed, market manipulation by Enron traders—the utilities began to lose large quantities of money on every kilowatt supplied. When Governor Grey Davis refused to allow the utilities to raise rates on consumers, they all declared bankruptcy. From that point on, California issued Energy Recovery Bonds to cover the revenue shortfall. In subsequent legislation the California legislature fixed most of the problems that had triggered the crisis. Nonetheless, the crisis and, in particular, the evidence of market manipulation to drive up prices by Enron shows the dangers of poorly executed deregulation. In contrast, regulation has succeeded in Texas and, internationally, in many countries, notably England. According to MIT expert Paul Joskow, the best results have been secured in countries that hewed to the textbook model of reform.[11]

A Return to Regulation?

Since 2001, several states have retreated from deregulation, notably Virginia. Other states have restored price caps or otherwise adopted measures to restrict the free movement of prices.

Critics of deregulation point to the California crisis and higher prices since 2002 as evidence that deregulation didn't work. Supporters of deregulation point to declining prices from 1996 to 2002 and lower prices overall since 1996 as evidence that partial deregulation has not adversely affected prices.

Both sides would agree that deregulation only went part way and the current system is a thing that neither regulated nor deregulated but more the former than the latter.

The 2005 Energy Policy Act and 2005 Public Utility Holding Company Act included new incentives for energy conservation and renewable energy and loosened restrictions segregating utilities from other companies. The 2007 Energy Act and 2009 American Recovery and Reinvestment Act allocated billions to modernize the grid and make it smarter. But, clearly, the work of reforming the electricity sector is unfinished. Indeed, it has barely begun. We still live in the world of Electricity 1.0.

The fact is that the current system is unsatisfactory in a variety of ways and incompatible with the rapid deployment of clean technology or of making good on the promise of the renewable energy revolution. The next chapter explores the structural roadblocks imposed by the current system in greater detail.

[11] Joskow, Paul, "Lessons Learned From Electricity Market Liberalization," *The Energy Journal, Special Issue. The Future of Electricity: Papers in Honor of David Newbery*, 2008, pp. 9–42.

VI. Structural Barriers to Change

While Electricity 1.0 is fraught with barriers blocking the rollout of clean technology, the real question is not what is wrong but why so much is wrong. The answer is that the entire existing system of electricity production and distribution is its own greatest barrier to change. It is the system that has created the current problems—an undersized grid, bias against new technologies, and dwindling R&D—inevitably and by design. The fact is that what needs to be fixed are not these symptoms but, rather, the structure of the industry itself that has caused the current unacceptable state of affairs.

Earlier this year the government took major steps to modernize the grid through appropriations in the American Reinvestment and Recovery Act. However, the fact is that no matter how much money the government sends its way Electricity 1.0 will never deliver more than it was designed to deliver a century ago: Reliability, cost containment in the short term, and rural reach. To take the energy network to the next level, Electricity 1.0 must be discontinued and Electricity 2.0 rolled out to take its place. But first, it is important that we identify the structural flaws and limitations of Electricity 1.0.

The Limitations of Electricity 1.0

The very structure that created the principle strengths of Electricity 1.0 has imposed formidable limitations on the network that have led to the symptoms mentioned above. Its regulatory structure has—

- Cut the connection between reward and performance and reward and risk, rewarding companies the same way whether they perform or not and regardless of whether they retreat or advance.
- Eliminated, through its regimentation, the competing ideas, strategies, and business models vital to progress and innovation.
- Removed any market discipline to pass judgment on the success or failure of new products and technologies.
- Given the force of law to standards and engineering that make electricity as much of a commodity as possible and that strip it of any features that might differentiate it in the market and provide an opportunity for innovation.
- Limited, through sanction of a single monopoly, innovation brought about through new market entrants. Sophisticated technology ecosystems, such as that in Silicon Valley surrounding information technology, typically involve personnel leaving one company to start others in order to capitalize on new ideas. This is impossible when competition is forbidden.
- Disenfranchised the consumer from any participation or involvement in product development and design.
- Led to flawed decision making due to bias and insulation from new ideas. Utilities that have always done it one way are likely—absent competition—to look askance at new ideas.

It is worth examining each of these structural roadblocks to progress in turn.

Guaranteed but limited returns. The structure of the state, rate-based system of regulation of utilities, which guarantees a fixed return on investment, has supported steady investment in capital equipment by utilities but removed any positive incentive to take risks on new technology that might work better than the older variety. This, more than any other factor, is the main reason for the lack of R&D in the industry. In effect, the lack of innovation and R&D in the industry is by design.

Guaranteed but limited returns have made it easy for utilities to raise capital and made their securities the proverbial favorite of widows and orphans. However, those same caps on returns have led to the sluggish, risk-averse profile of the industry. Why invest in new technology if you get the same return from old, low-risk technology? Why buy a cheaper, more efficient new technology when a more expensive, older technology will add more money to the rate base, increasing your profits? This set of perverse incentives has virtually ended innovation within most utilities.

To the degree R&D has taken place, Electricity 1.0 has moved it out of utilities to their suppliers, to large equipment manufacturers like General Electric, to vendors of nuclear power plants like Westinghouse and Areva, and to developers of solar technology, wind turbines, and other clean technologies like First Solar. However, as we shall see, this is at best a partial solution.

Conservative, risk-averse purchasing. While vendors, unlike utilities, can receive large returns on successful products, justifying the risk of R&D investments, they cannot entirely escape the risk-averse profile of the industry. In fact, the risk aversion and deep conservatism of utilities business strategies extends down through the value chain, suppressing risk taking and innovation at every level.

The market for electricity turbines is large, large enough to justify significant investments in new generations of products. Similarly, the promise of renewable solar technology has drawn a series of companies to invest in the space. More recently, Silicon Valley has become keenly interested in energy technologies, attracted by the fruition of many promising technologies and the apparent technology gap of an industry frozen in time that is far less invested in computers, for example, than seemingly low-tech industries such as retail, warehousing, and transportation.

However, the purchasing patterns of utilities are notoriously conservative, not by accident but because utilities must live within a rigid structure of return on investment and because each investment faces scrutiny not only from regulators but from advocates for consumers. The latter have the opportunity to scrutinize most investments in periodic rate cases before public service commissions and FERC. Lowering the quantity of investment on which utilities receive returns is the all-important metric for consumer advocates and public service commissioners. Although real consumers have shown a willingness to pay a premium for solar-generated electricity in place of the coal-fired variety, they have no ability to express those preferences in the marketplace because they are barred from that marketplace. Purchasing and all investment decisions at utilities are restricted to a small group of conservative decision makers whose ultimate concerns are governed not by the hope of making large returns which might incentivize them to innovate more, but rather by the fear of making a mistake.

There is no diversity in decision making of the type that arises in a healthy marketplace populated by multiple consumers with multiple opinions and multiple strategies or business models for making money. Instead, conformity of decision makers and conformity of opinion stemming from the common regulated structure works to suppress risk taking and reduce dollars available for new technologies, products, and services from the beginning to the end of the value chain.

<u>Lack of market discipline</u>. In turn, regardless of the purchasing decisions that ultimately get made, under the rate-base system there is no market discipline to sort out good investments from bad. Anything that regulators allow into the rate base—from paper clips to power plants—becomes a good investment for utilities since it contributes to their revenues, whether it was good, bad, cheap, or expensive. Anything that doesn't make it into the rate base disappears from sight, often for good. The developer of a great technology once turned down by the monopoly utility typically has nowhere else to go in that market. His or her only hope is to try a utility in another market. Once there, however, yet again there will typically be no market discipline to validate a truly good idea or expose a bad one. Rarely are there ever consequences to making the right or wrong decision.

<u>Standardization as a featureless commodity</u>. In the early days of electricity there were multiple varieties of electricity characterized by different voltages, formats—DC vs. AC—and bundles of service—power only, power and lighting, power at different times, and other differentiated product offerings.

Electricity has subsequently embraced standards to facilitate the movement of electricity over the network, a worthy goal insofar as standards lower transaction costs. And regulators have most obviously standardized the unit of power sold to consumers, namely the kilowatt hour, such that utilities almost never bundle power with other services and few utilities provide time-of-day pricing or much other variety in pricing plans. This approach is, indeed, typical of the regulated utility model.

The problem with this commoditization of the product supplied is that it has eliminated diversity and stifled freedom of creation. Standards created long ago have failed to adapt to the times and, while innovation has flourished in fields of electrical engineering outside the core transfer of electrical power (for example, in the creation of electronic devices, batteries, and power management of laptop computers), it has been nonexistent at the core.

One need only compare the wires in a modern house. Twenty years ago, the typical house had two wires—twisted copper pair wires for telephone service and 120 volt copper wire for electricity. Today, the communications options have multiplexed so that a high-end home is now constructed with up to six low voltage cables wired to each room, Cat5 or Cat6 for phone, Cat6 for computer, RG6 for video, and RG6 for audio and home theater. Some builders run HDMI and fiber as well. In contrast, builders still run, at most, 120 volt wire for electricity and 220 volt wire for air conditioning and certain appliances. Despite the proliferation of direct current devices such as cellular phones, music devices, and answering machines running at low voltage in the home, there has been absolutely no effort to introduce low-voltage direct current wiring. (The latter is particularly amenable to being fed through solar energy, which supplies direct current natively via a battery.)

This is not by accident; rather, it is a direct result of the sustained effort over many years to make electricity a featureless commodity devoid of product differentiation. A richer market would preserve the commodity value of raw power but multiplex it for different applications.

No free entry and limits to innovation from new companies. Finally, innovation often takes the form of new companies entering a market to exploit a new idea or new technology. In Silicon Valley and other high-tech centers, the phenomenon of executives leaving one company to start others—and, indeed, the development of a rich ecosystem characterized by the constant creation of new companies, executives moving among companies, and finance ready to support companies—is well documented.[12] This is, of course, impossible in a regulated industry where competition is barred by law and new entrants are forbidden. Indeed, laws go so far as to bar industrial users from running electric lines across the public streets of an industrial park or teaming up to share generation and storage costs, in many cases, through localized networks.

Of course, the existence of one legally protected monopoly as the distributor of the final good does not foreclose innovation in the utility's supply chain. And, indeed, clean technology has become a huge category of investment in Silicon Valley and other high-tech centers on the premise that an ecosystem analogous to those in information technology and life sciences can develop among suppliers to the utilities. It is at this level—one level away from the final good, electricity—that venture capitalists, technologies, and clean technology entrepreneurs are focusing their efforts.

Nonetheless, the absence of movement of people, new company formation, and other innovation-friendly characteristics of new-market entry at the final tier of the supply chain may exert a chilling effect and slow penetration of new technology at the final tier—beyond the chilling effect created by the lack of financial incentives cited above.

Disenfranchisement of the consumer. The approach of the venture and clean technology community in trying to drive innovation one step back from the consumer at the level of supplier to utilities, with the utility sitting as gatekeeper between the innovators and consumers, has the disadvantage of separating the innovation from those who would most appreciate it. Indeed, a feature of Electricity 1.0 that is a legacy of its 20th-century roots is the total disenfranchisement of the consumer.

Big Power treats the consumer in a manner analogous to how large 20th-century organizations treated the individual. The consumer has no rights and limited input into decision making. Whereas the consumer drove change in the information technology revolution, the consumer under Electricity 1.0 is imprisoned behind the wall of one-size-fits-all service—and barred, often by law, from taking control of his or her destiny even on his or her side of the meter.

[12] Saxenian, Anna, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*, Cambridge, MA: Harvard University Press, 1994, p. 226.

Flawed decision making. Insulation from competition and the absence of mechanisms to provide market-based accountability for decisions encourages flawed decision making by utilities. Perhaps the greatest examples of flawed decision making were the multi-billion dollar investments made by many utilities in nuclear plants that were never commissioned. Recently, utilities have been petitioning regulators to build large new transmission lines to draw power from long distances when it is possible that well sited distributed solar facilities might meet the same demand at a far lower cost in an environmentally friendly way (Box VI-A).

> **Box VI-A**
> **Flawed Decision Making under the Rate-Base System: The Sunrise Power Link Example**
>
> Improved network intelligence combined with distributed generation has the capability of saving money and enhancing network performance by providing distributed power alternatives to multibillion dollar transmission lines. But utilities, pursuing their rational interest under rate-based regulation, have an incentive to build such lines whether they are the best bet for ratepayers or not.
>
> In 2005, San Diego Gas & Electric (a Sempra Energy company) petitioned the California Public Utility Commission to build the $1.9 billion Sunrise Power Link 500 kV to transport cheap, gas-fired power from Arizona to California. Permission was recently granted.
>
> Advocates for renewable energy argued that the multi-billion dollar project is unnecessary, as solar plants situated at key points in the region could have supplied the same amount of power at a far lower cost (after deducting for the cost of the line). In this instance, SDG&E obviously had a huge financial incentive to build the new line, as once it enters the rate base it will generate guaranteed profits. However, ratepayers, if advocates for renewable energy are correct, will end up paying far more for gas-fired power than they might have paid for clean solar power.
>
> From a social welfare standpoint, and from that of the consumer, this decision by the utility (supported by the PUC) is clearly flawed. But, given the regulated structure of the industry it was rational for the utility to make it.

Regulation and Innovation, Generally

These problems should not be surprising as they are hardly unique to the regulated electricity industry. A large number of studies of innovation in regulated industries suggests that reduced innovation—and even problems like undersized capacity and a disempowered consumer—are endemic to all regulated industries.

During the period of transportation regulation, for example, little innovation took place in logistics. Not until deregulation of transportation took place in the 1980s, did logistics undergo the revolution it subsequently did that paved the way for the explosion of distribution of goods in the United States over the last two decades.

Similarly, during the period of regulation of telephone services, innovation slowed and consumers had very limited ability to express their preferences in the market. Empirical studies of the telecom industry in the U.S. and elsewhere confirm that which is all too apparent, namely that innovation dwindled prior to deregulation and increased dramatically afterwards. Since then, there has been far more innovation in the unregulated portions of the telecom industry than the regulated ones. The same is true of financial services and other formerly regulated industries that have undergone various degrees of deregulation.

The Impact of Partial Deregulation

It was, indeed, to address some of the problems described above, and with the goal of lowering cost over the long run, that in the 1990s Congress and FERC undertook an effort to deregulate the electricity industry and charged states with carrying out electricity reform. As discussed above, the deregulation ultimately enacted was partial, halting, and never completed. Over half the states did not deregulate, and those that did did so erratically in, initially, different ways.

While partial deregulation generated more competition, it preserved distribution monopolies. And the presence of a regulated distribution tier and *de*regulated generation tier has created problems of its own.

As discussed, a principal goal of regulation of the state-created utility monopolies has been to protect consumers against the classic monopoly abuse—excessive profits in the absence of competition.

Monopolies—because they have no competitors able to undercut them in price—can essentially pick the price at which they sell a commodity. They cannot determine how much of the quantity the public will buy at that price. They can charge more than the "equilibrium price" of a good, meaning the price that would prevail in the presence of competition. What economists call the monopolist's "market power" is particularly strong if the good in question is a necessity and demand for it "in-elastic" or unresponsive to price, meaning people must buy it whatever its cost.

Electricity demand, a host of economic studies have shown, is not responsive to price in the short term (though it is responsive to price in the long term, since people can eventually upgrade appliances or substitute other fuels). Because of the power of a monopoly utility to charge almost an unlimited price for electricity in the short term, however, limiting price has been a key goal of electricity regulation since municipalities licensed the first monopolies at the turn of the century.

While keeping prices low was good for consumers, since partial deregulation in the 1990s that goal has had a curious effect on suppliers.

Where utilities remained vertically integrated, the price at which utilities purchase power from their internal generating subsidiaries is academic. It merely alters which part of the company books more revenue. However, since partial deregulation, which has separated regulated utilities from generation, the price at which generators can sell is important because it determines the split in revenue between distributors and generators and the profitability and viability of the latter.

While regulation was adopted to protect consumers against monopolies, what has emerged following regulation is no longer a monopoly on supply but rather a monopoly on distribution and what economists call a "monopsomy" on purchase of power.

The Problem with Monopsomies or a Single Buyer

The problem with monopsomistic market power when exercised by a single buyer is that it tends to drive prices lower and discourage investment and innovation. The problem is particularly acute when the commodity is highly perishable, like electricity, in the short term. With a perishable commodity, in particular one with high fixed but low variable costs, the producer must sell the product at any price giving the monopsomist substantial market power. While the monopsomist can drive down prices in the short term, in the long term suppliers will find alternative uses for capital, lowering the supply of the commodity.

Lowering prices in the short term can benefit consumers. The single buyer (or payer), after negotiating lower prices, can theoretically pass the savings on to consumers. However, the lower price, over the long term if not the short term, will reduce supply, discourage investment, and limit innovation, which can lead to higher prices in the long run.

And there is also the potential for the monopsomist—in this case, the utility—to use its market power to drive down prices but, instead of passing the savings on to consumers, retain them for itself to boost profits or mask inefficiency.

Indeed, in pure economic terms a monopsomy is every bit as distortionary as a monopoly. With a monopoly, the problem is not just equity—the fact that the monopolist makes more than he or she would in a competitive market—but distortion. The extra money paid by hard-pressed consumers does not go away, it goes into the pocket of the monopolist. The monopolist can then invest it or spend it elsewhere, recycling the demand in the economy.

The problem of monopoly, beyond equity, is that consumers pay more than they should for the monopolized commodity, reducing their spending on other commodities they might desire, distorting the economy, and lowering overall welfare. It is for reasons of distortion as well as of equity that regulators have long sought to prevent or regulate monopolies.

In the case of the monopsomist, or single buyer, the money lost by the suppliers selling to the single buyer, similarly, does not disappear. It goes to the single buyer, who makes an outsized welfare gain. The single buyer, like the monopolist, then has additional money to invest or spend.

But, once again, the impact apart from equity is distortion of the economy. Too little spending for a product over the long term reduces investment, artificially diverting money to less efficient uses, producing a sub-optimal result for the economy overall, and, in the case of electricity, generating too little supply. While regulators have traditionally paid more attention to monopoly than monopsomy, largely because it is more common and affects the public, monopsomy is every bit as distortionary to the broader economy.

The Additional Impact of Bias

That is true even when the single buyer is acting entirely fairly as a rational, unbiased consumer. However, the absence of other buyers in a single-buyer market creates the potential—when the buyer is also active in related and ancillary markets for various forms of self dealing.

For example, if the monopsomist has a subsidiary that generates electricity, as many do, the monopsomist may choose to pay a price for electricity that advantages its interests at the expense of a competitor.

As an obvious example, it can underpay for the power. What its producing subsidiary loses from an excessively low price its distributing subsidiary recaptures through a higher profit margin.

The independent producer, however, objectively loses and will find itself, at best, deprived of funds needed for investment and, at worst, forced out of business.

Similarly, the monopsomist may make decisions regarding new technologies, standards, distribution lines, access, and other non-economic matters with adversarial economic impacts on different suppliers.

One solution to the problem of preferential dealing is for the monopsomist to divest itself of upstream and downstream operations that might permit it to favor internal channels to external firms.

Under the partial deregulation in effect since the late 1990s, however, some utilities remain entirely vertically integrated, severely disadvantaging competitive suppliers. Others, while they have divested much of their production capacity, retain some. Only a handful of utilities have entirely divested themselves of generating capacity. Note that even those utilities with no generation may still have an incentive to drive down prices without lowering them for consumers to mask inefficiency.

Ultimately it is not vertical integration itself that creates a problem but vertical integration in the absence of competition at any tier, which is to say monopoly at one or another tier. As long as rival suppliers, customers, and competitors can compete fairly in the marketplace, welfare is maximized. It is the existence of a dominant market position as buyer or seller through the absence of competition that creates the potential for self dealing, refusal to deal, *tying*, and other predatory practices. Where market dominance exists, policymakers, legislators, regulators, and courts have frequently restricted firms from participating in related markets due to the obvious potential for abuse.

Not so in electricity.

And, of course, the potential for preferential dealing in the absence of competition at one tier enables monopsomies to drive out or ward off competition at the supposedly competitive tier, re-establishing their vertical monopoly.

Locational Marginal Pricing

To combat the problem of a an unfair playing field against third party generators and simply to promote competition, in the course of electricity reform in the 1990s some states required utilities to sell off generation assets. Deregulating states also established wholesale markets, known as RTOs or ISOs, to provide market transparency, and required utilities to purchase some or all of their electricity in these markets.

California, in its misguided first try at deregulation, even went so far as to require utilities to buy *all* of their electricity in public markets. While intended to create a fair playing field, this requirement became a direct cause of the California crisis when prices spiked in late 2000, since California utilities had no alternative source of supply to sky-high spot purchases and no ability to raise prices on consumers. As a result, they went bankrupt.

Under the system that has emerged not only in the U.S. but globally—the preferred system for the wholesale exchange or power, known as locational marginal pricing (LMP) or security constrained, economic dispatch of power—self-regulating regions such as California, Texas, or the Pennsylvania, New Jersey, Maryland region establish wholesale markets for power administered by an RTO. The boundaries of the region also become a balancing region for power and load.

Within the region, the authorities identify a large number of nodes or geographic points around the area and conduct day-ahead and hour-ahead spot markets based on projected demand for electricity supplied to each point. Different prices at different nodes provide information about congestion or the difficulty in getting electricity from one point to another. In most markets, suppliers bid a price at which they will sell the power. Demand is filled in order of lowest to highest price; however, all suppliers receive the highest price the utility must pay to meet all of its demand.

In places with LMP the wholesale spot markets provide one channel for the sale of power, but utilities are also able to fill demand through direct contracts with generators and their own capacity if they have it insulating them from fluctuations on the spot market. The spot market, meanwhile, provides the final tranche of power and is an open, transparent platform where generators can sell their product without fear of gaming or insider dealing. (The final, last-minute adjustments to match power supply to customer load take place through so-called "regulation services," where flywheels, spinning reserve, or quick-start furnaces add small increments of power to fine tune frequency and voltage.)

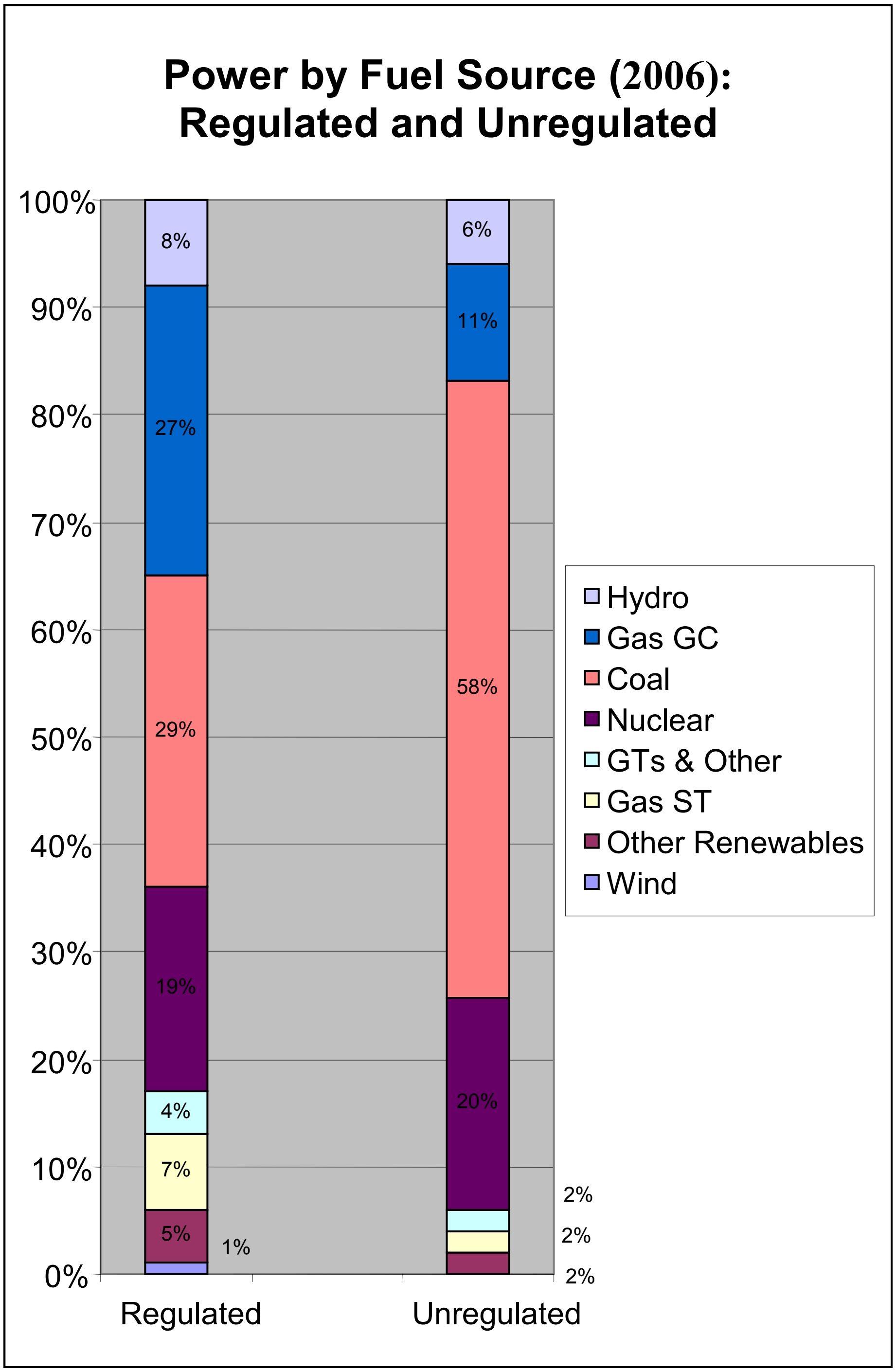
Indeed, spot market prices are often higher than long-term contract prices. As a result, many suppliers of alternative energy are quite happy to sell into the spot market. The problem, however, is that selling into the spot market subjects suppliers to market risk. Long term contracts, even if at a lower price, provide the promise of steady cash flow that providers can take to a bank as security for loans.

So, while the system of wholesale markets does provide an open transparent market for suppliers, they cannot avail themselves of it as fully as they might like due to the market risk inherent in spot price fluctuation and the preference of lenders for long-term contracts.

Moreover, in some markets utilities still have some ability to choose how much power they need to buy in the spot market—and, indirectly, what they may need to pay for it—by moderating how much they source through long-term contracts or their own generation.

In short, neither of the two main models for electricity regulation today—the regulated or partially unregulated model—is entirely hospitable to renewable energy. As Figure VI-1 (next page) shows, deregulated markets are more friendly to renewable energy than regulated ones. Of the two, the regulated market, which is closed to independent producers, is very inhospitable. But even the partially deregulated market presents obstacles to renewable producers trying to get their product to market.

Figure VI-1



Source: Energy Information Agency

Rethinking the Rationale for the Current System

Given the problems with the current system, it is worth examining the rationale for regulating electricity as a natural monopoly in the first place. Even Richard Ely, the intellectual godfather of the current system, believed a free market with real competition superior to government intervention. Modern economic theory has formalized the welfare benefits of an open market insofar as, according to the second fundamental welfare theorem of economics, welfare is maximized when goods trade in an open market at the market clearing equilibrium price. Government intervention, while necessary in some instances (with public goods where producers cannot exclude people from a service and it does not disappear from use, or where the benefits of a service are distant in time, as with scientific research or education), can only come at an efficiency price.

As discussed above, regulation of utilities proceeded in stages. After a period of free competition, municipalities began to license a single monopoly as they had for gas and water. Then states began to regulate the monopolies, ostensibly to rein in prices and corruption. The theory of natural monopoly used to justify the rate-based system of regulation was formalized only in the 1920s.[13] Since then, however, public choice theory, as it is known, has evolved so that today there is a diversity of opinion as to whether and under what circumstance natural monopolies exist.

The rationale for the idea of natural monopolies is that some goods have natural in-firm[14] economies of scale that enable a dominant firm to lower its average cost to a level where other firms cannot possibly compete. Usually this means that the business is capital intensive and has high-fixed relative to variable costs. By this argument, were a second utility allowed to put in duplicate electricity lines, for example, the lines would be unnecessary and therefore inefficient as the company would fail. Of course, precisely why "natural monopolies" require a government monopoly is unclear. If the monopoly is truly natural, as opposed to government-imposed, it should be able to ward off competition on its own without legal protection.

Expanding on this line of critique, some economists have argued that natural monopolies are a theoretic rationalization of a political act. AT&T, for example, achieved its monopoly status not by defeating the competition—it was only one of many competitors prior to World War I—but because the U.S. government nationalized the entire telephone industry at the outset of World War I and then privatized it as a regulated monopoly, ATT, once the war ended.[15] And in exchange for licensing monopolies in gas, water, and electricity, local politicians often received outright payoffs or opportunities to benefit from the monopoly business.

On the other hand, a legitimate rationale for consolidating utilities into a single monopoly was the inconvenience caused by multiple companies stringing wires over open spaces or digging up

[13] The idea was proposed by John Stuart Mill in the early 19th Century in the context of labor wage differentials, but it was not formalized until the 1920s.
[14] As opposed to industry-wide economies of scale that would be available to all producers. See Coase, Ronald, "The Nature of the Firm," *Economica*, 4 (1937):386–405.
[15] See DiLorenzo, Thomas J., "The Myth of the Natural Monopoly," in *The Review **of Austrian Economics*** Vol. 9, No. 2 (1996): 43–58 for an account of the history of views of electricity regulation and a summary of the argument against the concept of the natural monopoly.

the streets. (A similar rationale led most cities to license only one cable television company in the late 20th Century.) And, in the case of dammed rivers, many Americans also felt (and feel today) that hydropower ought to be public, not private. Yet another factor that argues for government involvement in the provision of electricity is that it is semi-rivalrous, meaning that if one person uses it it does not entirely disappear. (This is true in the sense that, while the electricity used by a home *is* consumed, once a large plant and network are built an additional user only nominally reduces the power available for other people.) This, according to some, makes electricity a "tolled" or "club" good that, according to the classic typology of private and public goods,[16] may require some government oversight lest private firms show favoritism in its provision.

While economists may debate the merits of a government enforced monopoly, they generally agree that, once a monopoly exists, it presents problems for the general welfare that may justify government intervention. The problem is that, once regulated, the government itself can prolong a monopoly's existence.

Certain things besides government patent favor a monopoly: The absence of competing technologies, a high conversion cost to switching technologies (lock-in), a large ratio of fixed to variable costs in an industry (which enables the monopolist to employ predatory pricing), and product standardization.

The opposite of these conditions—rapidly evolving technology, ease of switching, low fixed costs, and product differentiation—can undermine the monopoly by giving competitors opportunities to challenge the monopolist. In the electricity industry, and in other industries, however, innovation and product differentiation are precisely the things that regulation—not to mention the illegality of competition—has traditionally suppressed. In effect, then, regulation of a monopoly can potentially cause a vicious cycle, making the very competition necessary to supplant regulation that much more implausible, entirely apart from the fact that, in the case of electricity, it is actually illegal. It was the fact that the act of regulating a monopoly may ultimately prolong it that led Milton Friedman to turn against regulation of monopolies.

All told, the problems currently besieging today's electricity industry and blocking the proliferation of clean energy are unlikely to go away as long as Electricity 1.0 remains the dominant mode of electricity provision.

[16] Classic public choice theory uses two criteria: Excludability—whether it is possible to deny someone a good if they do not pay for it—and rivalry—whether the good is consumed when used or remains to be consumed again. This distinguishes between private goods and public ones. Private goods are excludable, meaning nonpayers can be excluded from receiving the goods, and rivalrous, meaning the goods can only be used once, allowing the private market to handle their allocation. In contrast public goods are not excludable, meaning people can free-ride on their creation, and nonrivalrous, meaning once created they can be given out for free, creating a market failure. The government is often well suited—using its coercive taxing authority—to remedy this collective action problem and provide a public good. Goods can also be both rivalrous and nonexcludable (common pooled resources) or nonrivalrous and excludable (club or tolled goods), creating four categories using the two criteria. For further discussion, see Samuelson, Paul, J., "The Pure Theory of Public Expenditure," *The Review of Economics and Statistics*, Vol. 36, No. 4 (Nov., 1954), pp. 387–389 and Ostrom, Elinor, and Vincent, "Public Goods and Public Choices, Workshop in Political Theory and Policy Analysis," Indiana University.

If America is serious about upgrading to Electricity 2.0, there is no alternative to removing these disincentives by reforming the structure of the industry.

Just how to transition to Electricity 2.0 is the subject of the next chapter.

VII. Unlocking the Economic Potential of the Open Electricity Network

Before discussing how to bring Electricity 2.0 about, it is desirable to recap its features.

Understanding Electricity 2.0

Unlike Electricity 1.0, Electricity 2.0 is clean and hospitable to renewable energy. It is characterized by falling, not flat or rising, prices, by energy abundance not shortages, and by a continual stream of new, innovative products. Recognizing that it lies at the heart of the energy network, it exalts in its network features. It is devoted to increasing the number of people on the network, the number of connections between them, the richness of those connections, and the types and varieties of interactions they permit.

While R&D and innovation have stalled in today's power industry, outside a few research organizations, such as EPRI and Department of Energy labs, Electricity 2.0 will restore innovation, research, new ideas, and faith in the future in the electricity sector.

In addition—

- Electricity 2.0 will reconnect risk with reward to reward good ideas and punish bad ones.
- It will restore diversity in business models, strategies, and ideas in lieu of the regimentation of the present system.
- It will subject old and new ideas alike, as well as every form of investment, to the discipline of market acceptance or rejection.
- It will encourage product differentiation, innovation, and versioning around the core commodity of electricity, leveraging the network infrastructure for a wider menu of services while retaining standardized grades of power for core applications.
- It will encourage new market entrants of all type, cross fertilization with other industries, entrepreneurship, and the free movement of people and ideas to promote change, creative thinking, and pollination across the sector.
- It will be intelligent, adaptive, robust, and self healing
- It will incorporate far more storage than exists today to provide redundancy and resilience.
- It will permit micronetworks and long distance networks alike to enrich the infrastructure for moving energy.
- It will incorporate open, plug and play standards to facilitate rich, wide interaction.
- It will build in authentication and multiple layers of security to recognize and repel all kinds of threats.
- It will, above all, empower consumers to participate in the electricity market, demand features and take action to help the environment, achieve energy independence, and strengthen the American economy.
- It will do this by opening up the network to consumers, industrial customers, small businesses, technologists, and others and bind them, not in the simple one-to-many

framework of Electricity 1.0 but in the many-to-one, one-to-one, and many-to-many framework of a truly democratic network architecture.

Achieving Electricity 2.0

As discussed above, the key to achieving *all* of the goals that make up Electricity 2.0 is by achieving *one* goal: Open up the Energy Network. Opening up the network will create the right incentives to drive the other outcomes on an ongoing basis.

To open it up, however, deep and complex reform of the rules and framework that perpetuate Electricity 1.0 must take place. Reform must go beyond the tentative state-by-state efforts that characterized partial deregulation in the 1990s. And, in all likelihood, it must go even beyond what is sometimes called the 'textbook model' of reform.

The Textbook Model of Reform

Since the 1980s, numerous countries have undertaken electricity reform including England (and Wales), the Scandinavian countries, New Zealand, and Argentina, in addition to U.S. states, some in conjunction with privatization. This history, encompassing various approaches, has yielded what has been called a textbook model of electricity reform. As described by MIT's Paul Joskow, the textbook model includes the following elements among others—

- Vertical breakup of monopolies, usually through divestiture but also through "Chinese Walls," into unregulated and regulated tiers, including an unregulated generation tier, a regulated distribution and network management tier, and a deregulated retail tier.
- Horizontal division of the generation tier into multiple pieces to ensure adequate competition among generators.
- Creation and designation of an *independent* system operator (ISO) for each "natural" geographic region of the network, with the responsibility of maintaining the network, ensuring its reliability, and scheduling generation to meet demand.
- Creation of markets within each region, managed by the ISO, to acquire the power needed to meet demand and allocate transmission capacity.
- Continued, performance-based regulation of the "residual" regulated portion of the original monopoly.
- "Unbundling" of retail tariffs to separate out the price of energy from that of other expenses, such as transmission, distribution, and overhead.

There are variants to this textbook model. Some regions, such as Texas and England since 2001, favor long-term contracts over the multiple spot markets found in LMP areas like New York. Some—again like Texas—have encouraged retail competition while others have not. However, when enacted properly, the model has worked reasonably well. In England, new generation, reliability, and productivity have risen while prices have stayed flat or have fallen. In turn, research suggests that the largest problems with deregulation—the California crisis, for example—occurred when regions deviated most from the model.

However, it is equally true that, while the textbook model has boosted renewable energy in the U.S., change has not been transformative. It has not led to major innovation or investment in the energy sector or to breakthrough improvements in electricity design in delivery. It has not led to large increases in generation capacity and has actually led to a lowering of R&D in the U.S.

It has not fully unlocked the potential of Electricity 2.0 because, in most cases, it has yet to fully empower the consumer, jumpstart innovation, launch new products and services, or accelerate adoption of clean technology and renewable power. Thus, the model provides a starting point for reform but not an end point.

Shortcomings of Partial Deregulation to Date

Extensive research on the costs and benefits of deregulation shows that while generally successful, it has not met expectations in all areas.

Indeed, the entire structure of partial deregulation to date—the division of the industry into a production tier, a utility tier, and a retail tier—reflects the historical one-way nature of electricity transmission from large plants enjoying economies of scale to substations to end users. However, Electricity 2.0 requires more equality between producers and consumers as more places and points on the network begin to generate and share power with one another.

Problems that continue to surface with partial deregulation include those listed below.

<u>Anemic retail</u>.

- While an active retail segment comprised of Energy Service Companies (ESCOs) has evolved to service large business and industrial customers, for residential consumers the difference between wholesale prices and retail prices is too low in most markets to cover customer acquisition and other costs.
- The high nonproduct costs of electricity (transport, capacity taxes, stranded cost recovery fees, etc.) have undermined development of a retail sector.
- Where power is primarily available in spot markets and transportable at fixed rates, retailers face difficulty differentiating their product relative to utilities.
- The lack of a competitive retail sector, the entrenched position of the utilities, and remaining legal barriers to new market entrants have stymied development of new last-mile or in-home services, such as power assurance and home power management.

<u>Lack of consumer empowerment</u>. A separate, vibrant retail sector would be less critical if consumers could interact directly with producers. But the legacy monopolies generally stand in the way.

- Consumers cannot readily buy power directly from producers.
- Rules discriminate against micronetworks, small-scale distributed generation, and community.

Diminished opportunities for producers. Producers, forced to sell into a monolithic market, lack the ability to brand their product, differentiate it, or otherwise compete on anything other than price. This works to the disadvantage of new technology and clean energy.

All three of these problems stem from one cause: The continuing existence of the residual monopoly as an inflexible, doctrinaire intermediary between network participants.

The Product Attributes of Electricity

Here it is worth recalling the product attributes of electricity.

Originally a menu of different product offerings, electrical energy after a century of regulation has been engineered into a featureless commodity that, once stepped up to a common voltage, is entirely fungible. Indeed, today's grid so mingles electrical energy that, once it enters the grid, it is physically impossible to track where it goes. Like water, energy from one source mixes with that from others so quickly that the energy retains no discernible memory of its source. Paper transactions merely try to capture what people think takes place.

While electrons retain no memory of their past, consumers do care about their history. In markets where consumers have the option to purchase renewable power, *a significant number* show a willingness to pay more for power that comes from renewable sources.

When California authorized what it calls "direct access" —the ability of customers to buy directly from energy suppliers in 2001—over 6,000 businesses representing over 13% of California's total power usage signed contracts in just three months, before the California Public Services Commission placed a moratorium on new contracts.[17] While companies switched most often for reasons of cost, residential customers switched due to a strong preference for renewable energy,[18] with about 60,000 or 1% of the total switching to green power from companies like Green Mountain Energy. The lower number reflected the significant barriers to switching which the program did not have time to overcome.

From a marketing perspective, therefore, electrons can be different and consumers can perceive as much difference and derive as much differing utility from coal-generated power and solar power as they perceive between long grain and basmati rice. As with other commodities, electricity is also indexed by time and price. Because of the difficulty in storing it, the congested grid, and constant fluctuations in demand, however, it is harder to compute the transport cost of electricity in order to translate the price of electricity at one time and place to that at another.

As discussed in Chapter VI, pooling orders for electricity among different customers and buying without concern for the source of the energy—the way electricity acquisition usually occurs today—discriminates against renewable energy. Just as mixing vintage wine with two buck chuck would destroy the perceived value of the vintage product, so mixing renewable and

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[17] The PUC did this to preserve the ability of the state–in its emergency role following California's energy crisis as electricity buyer–to bond against electricity revenues which direct access was seriously eroding.
[18] Hamm, Andrew F., "Direct-access electricity still has a shot, say Capitol insiders," *Silicon Valley/San Jose Business Journal,* July 18, 2003; http://sanjose.bizjournals.com/sanjose/stories/2003/07/21/story8.html.

regular energy does not reward renewable energy for the extra utility it might provide to consumers.

> **Box VII-A**
> **The Benefits of Electricity Trade**
>
> Currently, due to high levels of regulation and congestion on the network and despite its ability to travel at speeds close to that of light over existing wires, electricity is not widely traded. More capacity and a new electricity commerce layer on the network could fix this. But while high cost regions generally favor import of low cost energy, some people in electricity abundant regions such as the Northwest (with hydropower) and West Virginia (with abundant coal) have expressed worries that export of electricity would cause their local prices to rise.
>
> In fact, increasing exports of a locally produced commodity is perhaps the single best economic development strategy that any locality can pursue. Export of a locally produced good, be it corn from Iowa, financial services from New York or oranges from Florida generates an inflow of money that exerts a very positive multiplier effect on the local economy. It would no more make sense for the Pacific Northwest to restrict the export of hydro-electricity than it would make sense for Florida to restrict export of oranges, Texas the export of oil, or France's champagne region the export of champagne.

Were electricity treated not just as a commodity (Box VII-A) but rather as a product differentiated by source, branding, or other features, a collection of buyers might buy a very different set of product at a collection of very different prices than a single buyer charged with making the entire purchase.

Opening up the Network

The solution to every problem of Electricity 1.0 is to end the gate-keeping role of the single regulated monopoly and open up the network. The regulated utility—even under partial deregulation, separates consumers from producers. To restore true innovation, drive investment, spur R&D, and generate economic activity that improves society it is vitally important to break down the barriers that divide them. To do so means breaking through—or crossing over—the roadblock and, indeed, breaking down as well the distinction between producer and consumer. This is what is meant by opening up the network.

A Big Bang

Moreover, to secure the full benefits of Electricity 2.0 piecemeal changes are inadequate. Rather what is needed is the equivalent of a 'Big Bang' to unlock the potential of the network. The Big Bang strategy has been successful in other cases of regulatory reform, notably in London in financial services in 1986 (enabling London to eventually surpass New York in many measures of financial services) and in the U.S. for telecom in 1996. A Big Bang strategy has the advantage of setting the clear, consistent, and stable standards needed to attract investment—in contrast to continually changing standards that have hampered reform efforts to date. But, insofar as deviations from the textbook model have posed the greatest problems, it is important that if the industry is reformed all at once the elements of reform be well considered.

Other industries that have undergone reform provide insights into what works and what doesn't.

Electricity Compared with other Industries

First, it is important to recognize that reform of electricity—an industry of government-imposed local monopolies—is very different from reform of airlines, financial services, or trucking, where government regulated an oligopolistic *group* of companies, primarily by regulating prices. It is far easier to free an existing group of companies—the airlines, for example—from price controls than to spawn new competitors for an entrenched incumbent distribution monopoly. Because of these differences in industry structure, I will focus my discussion on the two deregulated industries most like electricity: Telecom and natural gas. Both featured government licensed, local monopolies with network effects. In both, a key justification for restricting competition was concern about multiple companies digging up streets (and consuming public resources). As with electricity, both telecom and gas included a single monopoly loop servicing the final user and providing a titanic barrier to competition (and concentrated control of long-distance transmission as well). Deregulation of both has been quite successful.

Natural Gas and Telecom

Prior to deregulation, both industries—telecom and natural gas—were large, regulated monopolies like electricity. Natural gas was especially similar insofar as it involves production of energy prior to distribution. There is no production tier with traditional telecom service (though there is with cable television and some data communications).

In both cases, after a lengthy period of germination a key event ushered in deregulation. In the case of natural gas the event was FERC Order No. 636 finalizing the unbundling of pipeline transmissions. In the case of telecom, it was the Telecommunications Act of 1996, which established rules for competition.

Comparing electricity with these other network businesses, several differences are evident.

- First, electricity is more difficult to handle and move than natural gas or data. Electricity lines are more dangerous, larger (for high-voltage transmission), and, because of inadequate storage, less fault tolerant. Proper supply of electricity currently requires precise load balancing to maintain system characteristics such as frequency, voltage, and reactive power.[19] In contrast, low-voltage data lines or fiber present little harm to their surroundings. Gas falls in between. Electricity places a premium on management of the network that improved network intelligence is only slowly mitigating through automation.
- Second, while all three services are ‘essential’ electricity is especially so, insofar as more things depend on it, a problem also aggravated by lack of storage in the network. Currently, many essential services, from water pumping stations to cash machines to electric lighting to computers, cease to work in the absence of power.
- Third, it is harder to run electric lines than data lines or even gas lines. Data can be easily transferred wirelessly, but wireless transfer of electricity—in spite of Tesla’s path

[19] Out of phase power is used by machinery. Reactive power is not available for most uses as it is power temporarily stored and released by impedance in the circuit. However, it is required for some applications. It can be thought of as a wave that, running out of phase with the main energy wave, alternately increases the energy and, in turn, reduces it, having no net impact but lowering real power relative to what it would be were the waves in synch.

breaking experiments a century ago—remains in its infancy. The first major competition to the Bell Telephone monopoly arose from microwave transmission of phone service by MCI, which leased land from farmers and others to erect microwave towers to transport long distance calls, undercutting AT&T (Box VII-B).

Box VII-B
The Carterfone Decision: A Landmark in Telecom and Network History

While the dismantling of the ATT monopoly and the introduction of competition in telecommunications went through many stages prior to 1996—including the Judge Greene decision to break up the Bell monopoly in 1984—one FCC decision stands out as such a landmark that, over 40 years later, some still describe telecom as BC and AC: Before Carterfone and After Carterfone.

Tom Carter was a Texan entrepreneur who, in the mid 1960s, wanted to attach a coupling device to the Bell network to enable cell phones then being developed to connect with landlines. AT&T barred him from connecting to their network. Carter took the case to the FCC and, in a landmark decision, won. The 1968 Carterfone decision by the FCC set a precedent for competition that continued with the open skies policy for satellites and other key policy decisions promoting interconnectivity and competition. The decision underscores the critical importance in a network-based business of granting open access to the network.

In contrast, it remains a very expensive proposition to run electric wire long distances to provide merchant transmission. (A few companies are doing this, however, and it is a very interesting development.) And, while underground superconducting cable is an intriguing alternative to overhead wires (used in Europe and, in the United States, now being piloted by Con Edison in New York), the technology remains expensive.

Apart from these key differences, many problems are more pronounced in electricity than in other network business. For example, as in any network electricity problems can cascade. But, in the case of electricity, cascading problems are more problematic than in air transportation or telecom because so many services depend on electricity.

Despite these differences, however, the reason reform proved so successful in telecom is that the regulatory regime enacted by Congress and the FCC created new players able to effectively compete with the utilities. While the utility continued to provide connectivity to the home, caps on rates—in particular, the cap on the price of a local call—enabled third parties, such as America Online and later Internet Service Providers, to overlay their networks on top of the monopolies.

The proliferation of other 'last mile' connectivity channels in the form of cellular service, wifi, cable wires, microwave transmission, and satellite communications, in turn, undermined the telephone utility's physical monopoly, which provided real competition in the sector and connected consumers with producers. Indeed, consumers became a major force in the telecommunications revolution, sometimes downloading millions of copies of new software programs in hours, for example, and often leading business and large customers in driving demand for and adoption of new products and services.

The combination of a new virtual network overlaying the hard wire network to the home and new wires or wireless connections into the home overcame the monopoly roadblock and paved the way for the telecom revolution. (Interestingly, the other main direction of telecom reform—

one similar to electricity reform, creation of CLECs or ‘competitive local exchange carriers’ and expected to compete with utilities in signing up customers for local service—proved less successful because, as with electricity, CLECs found it difficult to compete with the monopolies, their profit margin being largely set by law.)

Similarly, in natural gas FERC order 636, which finalized the unbundling of gas from transmission, the way was paved for gas producers to interact directly with consumers, bypassing the roadblock on competition and innovation formerly imposed by the pipeline companies. (It is interesting that natural gas has witnessed significant new finds in recent years as the industry has experienced a technical revolution.)

Electricity reform, however, has so far failed to overcome the roadblock imposed by utilities. Rather than bypassing the utility’s monopoly, the retail sector, spawned by partial deregulation, has tried with much difficulty to compete with the residual monopoly.

While regulators can force monopoly utilities to open up their networks to competitors and ‘unbundle’ the commodity—gas, phone service, or electricity—supplied from delivery of the commodity to your door, the lesson of the telecom revolution is that, as long as the utility retains a monopoly on delivery, competition is always tenuous, with the companies at the mercy of a rule change that would destroy their business. Of course, the monopoly on delivery is imposed and enforced by the government. With that protection in place, however, only government regulation can restrain the monopolist from exploiting the choke point at that tier to drive others out of business.

Far more successful in creating competition in telecom than the authorization of CLECs has been first the overlaying of a new open network, the Internet, on that supplied by the utility and then the proliferation of new physical channels of delivery.

In the case of gas, the creation of an open, physical delivery platform in place of the old transmission monopolies freed market participants to create a new network of commerce on top of the delivery platform.

In the case of electricity, overcoming the roadblock of the monopoly control of distribution will similarly require competition on a new network layer riding on top of the physical electricity connection—as opposed, merely, to efforts to create competition in signing up retail customers through Energy Service Companies (ESCOs)—and, if possible, competition in the physical space. If there is to be real competition with the utility at the retail level, it will require a second wire into the home.

Those, then, should be the key improvements of the Big Bang on the textbook model tried to date, initiatives to—

- overlay a new capability to connect consumers directly with producers, as well as any other participants on the network as the division between consumers and producers blurs; and
- encourage a second wire into the home.

The Second Electricity Wire

What might the second electricity wire be? Currently, cable and telephone companies already supply low-voltage power into the home as part of their communications services. One potential second wire might be USB cable or Cat 6 cable with Direct Current capability sufficient to charge the myriad electronic devices that now wastefully must reduce AC 120 volt power to DC 6 or 12 volt power.

Another possible low-voltage wire within the home might be 12 volt Direct Current power of the type used in automobiles.

Devices that might conceivably interact with the low voltage wiring system include solar power, which is ideally suited to trickle into a battery for low-voltage uses and the natively DC batteries used in cars.

State Federal Issues Surrounding Electricity Reform

In the United States, issues of electricity regulation are particularly complex because states have traditionally played a greater role in overseeing electricity than they have in telecommunications. A Big Bang for the electricity sector is likely to require federal legislation, FERC rulemaking, state legislation, and local rulemaking. It is vitally important that the different levels of government work in concert.

During partial deregulation efforts that took place in the 1990s, Congress and FERC left it to devise deregulatory regimes. The result was a variety of different regimes in the Northeast, California, and the Mid-Atlantic but, in most states, no action at all. For the Big Bang in electricity, the federal government must play a more assertive role, derived from its role in interstate commerce, to encourage states to open up their networks if the full benefits of Electricity 2.0 are to be realized.

Four Principles to Guide Reform

The nation should commit itself to a ‘Big Bang for Electricity Reform’. While the work will be great, four principles must guide reform.

- While not abandoning state regulation, the industry must move toward streamlined regional and national regulation that matches the borderless configuration of the network itself.
- Utilities must be freed to engage in more unregulated energy commerce outside the rate based system with the deregulated portion separated from the regulated portion by a Chinese wall (as in telecommunications).
- But, to spur them to innovate and ensure they do not exercise market power, competition must be extended far more deeply at the retail level and extended geographically to create new companies, drive innovation, and accelerate job creation. This should include a new open commerce platform over the physical connection and provide the opportunity for a second wire into the home.

- The network must be opened to more participants, vastly expanded and modernized, and equipped with open plug and play standards to facilitate its secure but widespread public use.

In addition to these general principles, the following steps should be included as part of reform.

- Promotion of open, national, plug and play network standards to facilitate producer-to-consumer electricity commerce. This should include a protocol governing the tariffs for connectivity and electricity transport to facilitate wheeling of power, open software, and technical standards to govern movement of power over the network and credit for utilities to consumers who purchase power directly from producers.
- Sitting authority for FERC to facilitate the long distance transmission of power.
- Licensing of utilities other than the primary monopoly to provide a second low-voltage wire into the home to facilitate low-voltage power charging and sharing.
- Deployment of a network of charging stations to accelerate electric drive cars.

To accomplish these goals, NDN proposes the following steps.

- President Obama should charter a commission comprised of network and electricity experts with the mandate to design a new open architecture to support Electricity 2.0 based on the three principles of: 1) empowerment of the American people, 2) open network design, and 3) broader and deeper competition.
- State regulators, FERC, utility executives, technologists, and other stakeholders must undertake a parallel effort to devise a new open architecture for Electricity 2.0.
- Congress in conjunction with the Administration must pass legislation to update and reform the American electricity industry.

In many ways, upgrading to Electricity 2.0 requires less change than has occurred in many other industries, from financial series to banking to media to transportation. However, it does require that the change take place at once to create a new platform for economic growth. The good news is that partial deregulation has provided valuable lessons as to what works and what doesn't. There is every prospect that real reform of the sector now will have a far greater chance of working than prior efforts.

Opening up the electricity network will create the necessary incentives to drive action on all other fronts.

- It will accelerate the buildout of wind, solar, and other renewable power.
- It will drive the development of new value-added services on the network as well as new categories of transactions based on peer-to-peer networking, micronets, and cogeneration.
- It will accelerate the placement of distributed storage around the network to improve resilience and accommodate intermittency.
- It will drive a revolution in clean transportation.
- It will improve efficiency.
- It will reduce consumption of fossil fuels.

While this is an ambitious agenda, it is an achievable one (Box VII-C). Most importantly, it is absolutely required if the United States is to address climate change, achieve energy security, and harness the economic benefits of clean technology.

Box VII-C
Imagining the Energy Future

Absent the current, highly restricted electricity market, it is easy to imagine many new and innovative services. Entrepreneurs, technologists, and others are exploring and, in some cases, already selling early versions of a variety of innovative services.

Micronets. Small networks serving industrial parks, office parks, corporate campuses, college campuses, and even networks of companies in urban agglomerations or rural areas are an attractive alternative to conventional power procurement. Exemption from rules barring power transfer across public streets, plug and play standards, and templates for community power agreements could increase this form of decentralized local power generation, particularly when coupled with storage.

Community Networks. Many communities similarly desire to produce their own power–particularly renewable power from solar or wind installations–but are stymied by complex, unfavorable rules and regulations. Once again, uniform standards and simple processes for setting up networks would facilitate this form of decentralized power sharing.

Power Assurance and Quality of Service. Given the large cost of power outages annually, electric utilities or third party providers could earn incremental revenue by guaranteeing power through quality of service, backup power arrangements, or onsite storage. Alternatively, companies or consumers willing to accept variations in power could receive a discount. Many cities have demand-response programs with larger power users currently to reduce demand during peak periods. These programs are rudimentary compared to what new technology could make possible.

Home Energy Management. Most consumers today have little information about energy usage and no ability to manage it. Software to manage power in the home controlling chips in devices or outlets could easily provide this capability to consumers.

Google has developed a piece of software called the Power Meter which tracks electricity usage in the home, enabling consumers to cut usage and save money. Common standards, access to data about usage, and clarification of legal issues would help people use software applications such as Google's to take control of their power footprint.

Demand-Response Networking. It is possible to imagine customers enrolling appliances- or electricity-consuming devices in a smart network able to provide demand-response to the grid. Appliances or even outlets equipped with a chip could reduce power on cue in response to a signal from power operators. Or, the network of chips with the capacity to cut usage could bid into wholesale markets, as demand-response companies like Eneroc are already doing.

Wireless Power Transmission and Charging. Wireless transfer of power was one of Tesla's greatest passions. Eighty years later (this year, in fact) Phillips (which makes an electric toothbrush that can be charged wirelessly), Nokia, Samsung, Duracell, and Texas Instruments formed the Wireless Power Consortium to create standards for wireless power. Wireless charging of phones using magnetic inductance may appear in 2011, according to trade reports.[20]

In an even more ambitious project, Nokia has developed a prototype of a phone that draws ambient power from the myriad electromagnetic emissions in today's large cities. Just as light can create electricity, all electro-magnetic energy contains energy. Drawing power through an antenna from assorted, wifi, radio, television, cell phone, and other signals, Nokia projects its phone can extend battery life by 10% or more. Future phones may not need batteries at all, drawing all their power from the air.

[20] Higgenbotham, Stacey, "10 Things to Know about Wireless Power, GigaOm, October 4, 2009; http://gigaom.com/2009/10/04/10-things-to-know-about-wireless-power/

Glossary:
The Alphabet Soup of Electricity

Alternating Current (AC). Alternating Current is current that moves alternately in one direction and then back again in a cycle. Typical AC current in the U.S. travels at what is known as a *frequency* of 50–60 cycles per second, meaning that in one second the current reverses direction 100–120 times. AC current is normally generated by a dynamo or revolving magnet that pushes current (at a right angle to the magnetic field) in one direction and then, as the dynamo revolves half way, pulls it back in the opposite direction. Dynamos are sometimes configured to provide three phases of current, meaning that a wave of charge is propelled and pulled back three times during each cycle. Alternating current has the advantage of being easily stepped up and down in potential. For long distance travel, stepping up the potential, which reduces the current by an equivalent percentage, can drastically reduce loss since losses are proportionate to the square of current but not affected by potential.

Direct Current (DC). Direct current is current that flows in only one direction from a higher to a lower potential. Though DC, championed by Edison, lost out to AC championed by Westinghouse, during the War of the Currents, most electronic devices use direct current and therefore require transformers and inverters in order to make use of AC power. DC current has the advantage in circuit design that voltages used in transistors do not reverse and current can flow directly into capacitors for storage. Higher voltage DC current is still supplied to industrial customers and for elevator operation in some older cities, but its use is being phased out. DC current is also used for high-volume long-distance power transmission by merchant providers because it can be provisioned to multiple customers without concern for phase.

Energy Regulatory Commission of Texas (ERCOT). ERCOT is the Interstate Systems Operator that administers Texas. Because the Texas grid is largely disconnected from those in other states, ERCOT is not subject to FERC jurisdiction.

Federal Energy Regulatory Commission (FERC). The successor to the Federal Power Commission founded in 1920 to coordinate hydropower development and renamed as part of the Department of Energy Organization Act of 1977, FERC is an independent commission within but independent from the Department of Energy with authority over electricity transmission, oil movement, and gas resale that crosses state lines. One of its key roles is to adjudicate rate cases filed by utilities for the cross state provision of power. Other roles of FERC include monitoring the reliability of bulk transmission of power.

FERC Order 888. Issued by FERC in 1996, FERC Order 888, which effectively launched partial deregulation by opening the grid to independent power producers, prompted some states to deregulate their industries to protect their regulated utilities from low-cost producers in neighboring states.

FERC Order 889. This order, sometimes called the 'open access order', provided detailed directions on how market participants should interact through OASIS nodes, a system for posting and keeping track of market transactions and the movement of power.

Interstate System Operator (ISO). An ISO is an RTO (see below) that has met certain requirements and been accredited to administer an interstate region. Examples of ISOs include the PJM Interconnection and the New York Independent System Operator.

Locational Marginal Pricing (LMP). LMP is the practice since deregulation of holding auctions for the purchase of electricity at multiple locations. Under LMP, a market authority, normally the ISO or RTO, holds regular auctions at multiple points. The differing pricing at different points reflect local supply and demand at that point and provide information about congestion. Under the LMP system, the authority accepts all bids in order of lowest price until demand is fulfilled. All bidders normally receive the highest bid, which is presumed to be the market clearing price.

National Energy Reliability Commission (NERC). Founded in 1968 as the National Energy Reliability Council and renamed in 2006, NERC is a voluntary organization with the mission of ensuring the reliability of bulk power in North America. Among other responsibilities it produces NERC or E-tags designed to track bulk power transactions across the network.

Net Metering. The ability of a customer who generates power to sell electricity back to the grid, (ie., receive credit for net electricity flowing onto the grid).

Rate Base. The rate base is a category of asset of utilities on which they are permitted to receive a return generally set by statute. In order to place investments within the rate base, utilities must ordinarily go through a rate case proceeding in which the Public Service Commission (or for interstate cases, the FERC) rules on the validity of placing the investment in the rate base.

Regional Transmission Organization (RTO). An RTO is an organization that oversees bulk power flows within interstate regions, administers wholesale power markets, and engages in reliability planning. RTOs are similar to ISOs, but they have not yet applied for nor received ISO status.

Stranded Costs. Stranded costs are the costs of investments placed in the rate base where a utility has not yet received a return adequate to pay for the investment.

Wheeling. Wheeling is when electricity users buy power from producers and pay separately for transmitting the power over the network.

About Michael Moynihan

NDN's Green Project Director Michael Moynihan is currently a William Bowen Merit Fellow at The Woodrow Wilson School of Public and International Affairs at Princeton University and on the faculty of New York University. In 1999, Mr. Moynihan founded the first Internet video sharing community and Web site, AlwaysonTV, pioneering such innovations as personal video channels and video greetings. From 1996 to 1999, he served in the Clinton Administration in which he held the Internet portfolio and advised Secretaries Robert Rubin and Lawrence Summers as Senior Advisor for Electronic Commerce. While in the Clinton Administration, he led successful efforts to pass the Internet Tax Freedom Act, helped negotiate e-commerce agreements on payments, taxation and other issues with the European Union and Japan and oversaw the e-commerce efforts of Treasury's 140,000 employees. Prior to assuming the Internet portfolio, he advised Secretaries Rubin and Summers on a variety of other issues including managing debt crises, reforming the global financial architecture, balancing the budget and modernizing the IRS.

Mr. Moynihan has been a fellow of the Center for Strategic and International Studies and was the Robert C. Seamans Fellow in Technology and Public Policy at Harvard University's John F. Kennedy School of Government. He holds degrees from Columbia and Harvard and is currently a PhD candidate at Princeton.

Mr. Moynihan is the author of the critically acclaimed book, *The Coming American Renaissance* (Simon & Schuster) and other books. His forthcoming book, *The Choice: The History of Freedom* (Palgrave-McMillan) is scheduled for publication in 2010. His writing has appeared in *Harper's*, *The New York Times*, *The Washington Post* and other publications. He also is the author of an original paper for NDN entitled *Investing in Our Common Future: U.S. Infrastructure* (November 2007).