

**The German Energy Transition:
The Internet of Things,
Zero Marginal Cost Renewable Energy,
and the Third Industrial Revolution**

By Jeremy Rifkin

Introduction

Germany is embarking on a bold new journey to transform its energy regime and usher-in a new economic paradigm. To grasp the enormity of the economic change taking place, we need to understand the technological forces that have given rise to new economic systems throughout history. Every great economic paradigm requires three elements, each of which interacts with the other to enable the system to operate as a whole: new communication technologies to more efficiently manage economic activity; new sources of energy to more efficiently power economic activity; and new modes of transportation to more efficiently move economic activity.

In the 19th century, steam-powered printing and the telegraph, abundant coal, and locomotives on national rail systems gave rise to the First Industrial Revolution. In the 20th Century, centralized electricity, the telephone, radio and television, cheap oil, and internal combustion vehicles on national road systems converged to create an infrastructure for the Second Industrial Revolution.

The Third Industrial Revolution

Today, Germany is laying the ground work for the Third Industrial Revolution. The digitalized Communication Internet is converging with a digitalized renewable Energy Internet, and a digitalized automated Transportation and Logistics Internet, to create a super-Internet of Things (IoT). According to Cisco, German industry is currently leading the world in the deployment of Internet of Things infrastructure. In the Internet of Things era, sensors embedded in devices are being attached to resource flows, warehouses, road systems, factory production lines, the electricity transmission grid, offices, homes, stores, and vehicles, continually monitoring their status and performance and feeding Big Data in real-time to the Communication, Energy, and Transportation and Logistics Internets, providing up to the moment information for managing, powering, and moving economic activity across the myriad value chains in a smart Digital Germany. For the first time in history, the entire human race will have access to much of the information flowing through the economy, allowing them to collaborate directly with one another in vast laterally scaled economic networks, facilitating the democratization of economic life.

The digitalization of communication, energy, and transportation also raises risks and challenges, not the least of which are guaranteeing network neutrality, preventing the creation of new corporate monopolies, protecting personal privacy, ensuring data security, and thwarting cyber-crime and cyber-terrorism. The European Commission has already begun to address these issues by establishing the broad principle that “privacy, data protection, and information security are complimentary requirements for Internet of Things services.”

In this expanded digital economy, German enterprises connected to the Internet of Things can use Big Data and analytics to develop algorithms that speed efficiency, increase productivity, and dramatically lower the marginal cost of producing and distributing goods and services, making German businesses more competitive in an emerging post-carbon global marketplace. (Marginal cost is the cost of producing an additional unit of a good or service, after fixed costs have been absorbed.)

The marginal cost of some goods and services in a digital Germany will even approach zero, allowing millions of prosumers connected to the Internet of Things to produce and

exchange things with one another, for nearly free, in the growing Sharing Economy. Already, a digital generation is producing and sharing music, videos, news blogs, social media, free ebooks, massive open online college courses, and other virtual goods at near zero marginal cost. The near zero marginal cost phenomenon brought the music industry to its knees, shook the television industry, forced newspapers and magazines out of business, and crippled the book publishing market.

While many traditional industries suffered, the zero marginal cost phenomenon also gave rise to new entrepreneurial enterprises including Google, Facebook, Twitter, and YouTube, and thousands of other Internet companies, who reaped profits by creating new applications and establishing the networks that allow the Sharing Economy to flourish.

Economists acknowledge the powerful impact near zero marginal cost has had on the information goods industries but, until recently, have argued that the productivity advances of the digital economy would not pass across the firewall from the virtual world to the brick-and-mortar economy of energy, and physical goods and services. That firewall has now been breached. The evolving Internet of Things will allow conventional businesses enterprises, as well as millions of prosumers, to make and distribute their own renewable energy, use driverless electric and fuel cell vehicles in automated car sharing services, and manufacture an increasing array of 3Dprinted physical products and other goods at very low marginal cost in the market exchange economy, or at near zero marginal cost in the Sharing Economy, just as they now do with information goods.

The Renewable Energy Internet

For example, the bulk of the energy we use to heat our homes and run our appliances, power our businesses, drive our vehicles, and operate every part of the global economy will be generated at near zero marginal cost and be nearly free in the coming decades. That's already the case for early adopters in Germany who have transformed their homes and businesses into micropower plants to harvest renewable energy on-site. Currently, twenty-seven percent of the electricity powering Germany comes from solar and wind renewable energies. By 2020, thirtyfive percent of the electricity powering Germany will be generated by solar and wind energies. The quickening pace of renewable energy deployment is due, in large part, to the plunging cost of solar and wind energy harvesting technologies. The fixed costs of solar and wind harvesting technologies have been on exponential curves for more than 20 years, not unlike the exponential curve in computing. In 1977, the cost of generating a single watt of solar electricity was \$76. By 2015, the cost had plummeted to \$0.36. After the fixed costs for the installation of solar and wind are paid back—often as little as 2 to 8 years—the marginal cost of the harvested energy is nearly free. Unlike fossil fuels and uranium for nuclear power, in which the commodity itself always costs something, the sun collected on rooftops and the wind travelling up the side of buildings are free. In some regions of Europe, solar and wind energy are already as cheap, or cheaper, than fossil fuel or nuclear generated energy.

The impact on society of near zero marginal cost solar and wind energy is all the more pronounced when we consider the enormous potential of these energy sources. The sun beams 470 exajoules of energy to Earth every 88 minutes—equaling the amount of energy human beings use in a year. If we could grab hold of one-tenth of 1 percent of the sun's energy that reaches Earth, it would give us six times the energy we now use across the global economy. Like

solar radiation, wind is ubiquitous and blows everywhere in the world—although its strength and frequency varies. A Stanford University study on global wind capacity concluded that if 20 percent of the world’s available wind was harvested, it would generate seven times more electricity than we currently use to run the entire global economy. The Internet of Things will enable businesses and prosumers to monitor their electricity usage in their buildings, optimize their energy efficiency, and share surplus green electricity generated on-site with others across nations and continents.

The Energy Internet is comprised of five foundational pillars, all of which have to be phased-in simultaneously for the system to operate efficiently. First, the introduction of feed-in tariffs and other incentives, to encourage early adopters to transform buildings and property sites into micro-power generation facilities. The feed-in tariffs guarantee a premium price above market value for renewable energies generated locally and sent back to the electricity grid. While the cost of subsidizing the new renewable energies is passed onto rate payers by the electricity companies, placing a short term burden on businesses and homeowners, in the mid-to long-term, Germany will enjoy near zero marginal cost energy and a dramatic increase in efficiency and productivity across the economy, resulting in sustainable economic growth far into the future. In fact, feed-in-tariffs have been so successful in scaling-up renewable energies and reducing the fixed and marginal costs of generating green electricity, that in many regions they are being phased-out in a short period of time as the new energies become as cheap, or cheaper, than fossil fuels and nuclear power. By contrast, fossil fuel generated power continues to enjoy deep subsidies despite more than a century of market penetration. Second, the retrofitting of buildings and other infrastructure to make them more energy efficient, and the installation of renewable energy technologies—solar, wind, etc.—to generate power for immediate use or for delivery back to the electricity grid for compensation. Third, embedding storage technologies—hydrogen fuel cells, batteries, water pumping, etc.—at local generation sites and across the electricity grid to manage both the flow of intermittent green electricity and the stabilization of peak and base loads. Fourth, the installation of advanced meters in every building, and the introduction of other digital technology to convert the electricity grid from servo mechanical to digital connectivity to manage multiple sources of energy flowing to the grid from local generators. Fifth, equipping parking spaces with charging stations to allow electric and fuel cell vehicles to secure power from the Energy Internet, as well as sell power back to the electricity grid.

The phase-in and the integration of the above five pillars will transform the German electricity grid from a centralized to a distributed electricity system, and from fossil fuel and nuclear generation, to renewable energy. In the new system, every business, neighborhood, and homeowner in Germany becomes the producers of electricity, sharing their surplus with others on a smart Energy Internet.

A decade ago, four giant vertically integrated electricity generating companies— E.ON, RWE, EnBW, and Vattenfall—produced much of the electricity powering Germany. Today, these companies are no longer the exclusive arbiters of power generation. In recent years, farmers, urban dwellers, and small and medium sized enterprises (SME’s) established electricity cooperatives across Germany. Virtually all of the electricity cooperatives were successful in securing low interest loans from banks to install solar, wind, and other renewable energies onsite. The banks were more than happy to provide the loans, assured that the funds would be paid back by the premium price the cooperatives would receive—via feed-in-tariffs—from selling the new

green electricity back to the grid. Today, the majority of the green electricity powering Germany is being generated by small players in electricity cooperatives. The big four electricity generating companies are producing less than 7 percent of the new green electricity that's taking Germany into a Third Industrial Revolution.

While these traditional vertically integrated power companies proved quite successful in generating relatively cheap electricity from traditional fossil fuels and nuclear power, they have not been able to effectively compete with local electricity cooperatives whose laterally scaled operations are better adept at managing energy harnessed by thousands of small players in broad collaborative networks. Peter Terium, CEO of RWE, the German-based energy company, acknowledges the massive shift taking place in Germany from centralized to distributed power, and says that the bigger power and utility companies "have to adjust to the fact that, in the longer term, earning capacity in conventional electricity generation will be markedly below what we've seen in recent years."

A growing number of electricity generating companies are coming to grips with the new reality of democratized energy and are changing their business model to accommodate the new Energy Internet. In the future, their income will increasingly rely on managing their customers' energy use. The electricity companies will mine Big Data across each of their clients' value chains and use analytics to create algorithms and applications to increase their aggregate energy efficiency and productivity, and reduce their marginal cost. Their clients, in turn, will share the efficiency and productivity gains back with the electricity companies in what are called "Performance Contracts." In short, power companies will profit more from managing energy use more efficiently, and selling less rather than more electricity.

The Automated GPS-Guided Transportation and Logistics Internet

The meshing of the Communication Internet and the Energy Internet makes possible the build-out and scale-up of the automated Transportation and Logistics Internet. Again, according to Cisco, Germany's automotive industry is deploying the IoT to advance semi-autonomous driving, positioning the industry at the center of the emerging automated Transportation and Logistics Internet. The convergence of these three Internets comprise the kernel of the Internet of Things platform for managing, powering, and transporting goods and services in a Third Industrial Revolution economy. The automated Transportation and Logistics Internet is made up of four foundational pillars, which, like the Energy Internet, have to be phased-in simultaneously for the system to operate efficiently. First, as mentioned previously, charging stations will need to be installed ubiquitously across land masses, allowing cars, buses, and trucks to power up or send back green electricity to the grid. Second, sensors need to be embedded in devices across logistics networks allowing factories, warehouses, wholesalers, retailers, and end users to have up-to-the-moment data on logistical flows that affect their value chain. Third, the storage and transit of all physical goods will need to be standardized so that they can be efficiently passed off to any node and sent along any passageway, operating across the logistics system in the same way that information flows effortlessly and efficiently across the World Wide Web. Fourth, all of the operators along the logistics corridors need to aggregate into collaborative networks to bring all of their assets into a shared logistical space to optimize the shipment of goods, taking advantage of lateral economies of scale. For example, thousands of warehouses and distribution

centers might establish cooperatives to share unused spaces, allowing carriers to drop off and pick up shipments using the most efficient path on route to their destination.

The Internet of Things platform will provide real-time logistical data on pick-up and delivery schedules, weather conditions, traffic flows, and up-to-the-moment information on warehouse storage capacities on route. Automated dispatching will use Big Data and analytics to create algorithms and applications to ensure the optimization of aggregate energy efficiencies along the logistical routes and, by so doing, dramatically increase productivity while reducing the marginal cost of every shipment.

By 2030, at least some of the shipments on roads, railways, and water will likely be carried out by driverless electric and fuel cell transport and drones, powered by near zero marginal cost renewable energies, and operated by increasingly sophisticated analytics and algorithms. Driverless transport and drones will accelerate productivity and reduce the marginal labor cost of shipping goods toward near zero on a smart automated Transportation and Logistics Internet.

The erection of the automated Transportation and Logistics Internet also transforms the very way we view mobility. Today's youth are using mobile communication technology and GPS guidance on an incipient automated Transportation and Logistics Internet to connect with willing drivers in car sharing services. Young people prefer access to mobility over ownership of vehicles. Not surprisingly, "Germany has become the world's biggest user of car-sharing services, accounting for more than half of all one-way journeys taken worldwide." Future generations will likely never own vehicles again in a smart automated mobility era. For every vehicle shared, however, 15 vehicles are eliminated from production. Larry Burns, the former Executive Vice President of General Motors, and now a professor at the University of Michigan, did a study of mobility patterns in Ann Harbor, a mid-sized American city, and found that car sharing services can eliminate 80% of the vehicles currently on the road, and provide the same, or better, mobility at a lesser cost.

There are currently a billion cars, busses, and trucks crawling along in traffic in dense urban areas around the world. Gasoline-powered internal combustion vehicles were the centerpiece of the Second Industrial Revolution. The mass production of these vehicles devoured significant amounts of the Earth's natural resources. Cars, busses, and trucks also burn massive amounts of oil and are the third major contributor to global warming gas emissions, after buildings and beef production and related agricultural production practices. Burns' study suggest that 80% of the vehicles currently on the road are likely to be eliminated with widespread adoption of car sharing services over the course of the next generation. The remaining 200 million vehicles will be electric and fuel cell transport, powered by near zero marginal cost renewable energy. Those shared vehicles, in turn, will be driverless and running on automated smart road systems.

The long-term transition from ownership of vehicles to access to mobility in driverless vehicles on smart road systems will fundamentally alter the business model for the transportation industry. While the big auto manufacturers in Germany and around the world will produce fewer vehicles over the course of the next 30 years, they will likely increasingly reposition themselves as aggregators of the global automated Transportation and Logistics Internet, managing mobility services and logistics.

The convergence of the Communication Internet, renewable Energy Internet, and automated Transportation and Logistics Internet in an operating kernel becomes the global brain for an Internet of Things cognitive infrastructure. This new digital platform fundamentally changes the way we manage, power, and move economic activity across the value chains and networks that make up the global economy. The digitalized Internet of Things platform is the core of the Third Industrial Revolution.

Distributed 3D-Printing

Virtually every industry in Germany will be transformed by the Internet of Things platform and the phasing-in of zero marginal cost energy and a Third Industrial Revolution. For example, a new generation of micro manufacturers, using 3D-printing technology, are beginning to plug in to the insipient IoT, and dramatically increasing their productivity while reducing their marginal costs, enabling them to outcompete the formerly invincible global manufacturing firms, organized around vertically integrated economies of scale. 3D printing is the manufacturing model that accompanies an IoT economy. And, according to MakerBot, “Germany has also long been the European hub for 3D printing as overall interest in 3D printing has grown throughout Europe.”

In 3D printing, software directs molten feedstock inside a printer to build up a physical product layer by layer, creating a fully formed object, even with moveable parts, which then pops out of the printer. Like the replicator in the Star Trek television series, the printer can be programmed to produce an infinite variety of products. Printers are already producing products from jewelry and airplane parts to human prostheses, and even parts of cars and buildings. And cheap printers are being purchased by hobbyists interested in printing out their own parts and products. The consumer is beginning to give way to the prosumer as increasing numbers of people become both the producer and consumer of their own products.

The early practitioners of 3D printing have made strides to ensure that the software used to program and print physical products remains open source, allowing prosumers to share new ideas with one another in do-it-yourself (DIY) hobbyist networks. The open design concept conceives of the production of goods as a dynamic process in which thousands—even millions—of players learn from one another by making things together. The elimination of intellectual property protection also significantly reduces the cost of printing products, giving the 3D printing enterprise an edge over traditional manufacturing enterprises, which must factor in the cost of multiple patents. The open-source production model has encouraged exponential growth.

The 3D printing production process is organized completely differently than the manufacturing process of the First and Second Industrial Revolutions. Traditional factory manufacturing is a subtractive process. Raw materials are cut down and winnowed and then assembled to manufacture the final product. In the process, a significant amount of the material is wasted and never finds its way into the end product. With three-dimensional printing, the software is directing the molten material to add layer upon layer, creating the product as a whole piece. Additive manufacturing uses one-tenth of the material of subtractive manufacturing, giving the 3D printer a dramatic leg up in efficiency and productivity. 3D printing is projected to grow at a blistering compound annual rate of 106% between 2012 and 2018.

3D printers can print their own spare parts without having to invest in expensive retooling and the time delays that go with it. With 3D printers, products can also be customized to create a single product or small batches designed to order, at minimum cost. Centralized factories, with their capital-intensive economies of scale and expensive fixed-production lines designed for mass production, lack the agility to compete with a 3D production process that can create a single customized product at virtually the same unit cost as producing 100,000 copies of the same item.

Making 3D printing a truly local, self-sufficient process requires that the feedstock used to create the filament is abundant and locally available. Staples—the office supply company—has introduced a 3D printer, manufactured by Mcor Technologies in its store in Almere, the Netherlands, that uses cheap paper as feedstock. The process, called selective deposition lamination (SDL), prints out hard 3D objects in full color with the consistency of wood. The 3D printers are used to manufacture craft products, architectural designs, and even surgical models for facial reconstruction. The paper feedstock costs a mere 5 percent of previous feedstocks. Other 3D printers are using recycled plastic, paper, and metal objects as feedstock at near zero marginal cost.

A local 3D printer can also power his or her fabrication lab with green electricity harvested from renewable energy onsite or generated by local electricity cooperatives. As previously mentioned, small- and medium-sized enterprises in Germany are already beginning to collaborate in regional green-electricity cooperatives to take advantage of lateral scaling. With the cost of centralized fossil fuels and nuclear power constantly increasing, the advantage skews to small- and medium-sized enterprises that can power their factories with renewable energies whose marginal cost is nearly free.

Plugging into an IoT infrastructure at the local level gives the small manufacturers one final, critical advantage over the vertically integrated, centralized enterprises of the nineteenth and twentieth centuries: they can power their vehicles with renewable energy from the Energy Internet whose marginal cost is nearly free, significantly reducing their logistics costs along the supply chain and in the delivery of their finished products to users.

The new 3D printing revolution is an example of “extreme productivity.” The distributed nature of manufacturing means that anyone and eventually everyone can access the means of production, making the question of who should own and control the means of production increasingly irrelevant for a growing number of goods.

Many of Germany’s global manufacturing enterprises will continue to flourish, but will be fundamentally transformed by the democratization of manufacturing, which favors a high-tech renaissance for small and medium sized enterprises. In the future, Germany’s manufacturing giants will increasingly partner with a new generation of 3D-printing small and medium sized enterprises in collaborative networks. While much of the manufacturing will be done by SME’s that can take advantage of the increased energy efficiencies and productivity gains of lateral economies of scale, the giant enterprises will increasingly find value in aggregating, integrating, and managing the marketing and distributing of products.

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The peer to peer nature of the Internet of Things platform allows millions of disparate players—small and medium sized businesses, social enterprises, and individuals—to come

together and produce and exchange goods and services directly with one another, eliminating the remaining middle men that kept marginal costs high in the Second Industrial Revolution. This fundamental technological transformation in the way economic activity is organized and scaled portends a great shift in the flow of economic power from the few to the multitudes and the democratization of economic life.

It is important to emphasize that the transition from the Second to the Third Industrial Revolution will not occur overnight, but, rather, take place of over thirty to forty years. Many of today's global corporations will successfully manage the transition by adopting the new distributed and collaborative business model of the Third Industrial Revolution while continuing their traditional Second Industrial Revolution business practices. In the future, capitalist enterprises will likely find more value in aggregating and managing laterally scaled networks than in selling discrete products and services in vertically integrated markets.

Rethinking Economics in an Ecological Era

The transformation to an Internet of Thing infrastructure and a Third Industrial Revolution paradigm is forcing a wholesale rethinking of economic theory and practice. The unleashing of extreme productivity wrought by the digitalization of communication, energy, and transportation is leading to a reassessment of the very nature of productivity and a new understanding of ecological sustainability. Conventional economists fail to recognize that the laws of thermodynamics govern all economic activity. The first and second laws of thermodynamics state that “the total energy content of the universe is constant and the total entropy is continually increasing.” The first law, the conservation law, posits that energy can neither be created nor destroyed—that the amount of energy in the universe has remained the same since the beginning of time and will be until the end of time. While the energy remains fixed, it is continually changing form, but only in one direction, from available to unavailable. This is where the second law of thermodynamics comes into play. According to the second law, energy always flows from hot to cold, concentrated to dispersed, ordered to disordered. For example, if a chunk of coal is burned, the sum total of the energy remains constant, but is dispersed into the atmosphere in the form of carbon dioxide, sulfur dioxide, and other gases. While no energy is lost, the dispersed energy is no longer capable of performing useful work. Physicists refer to the no-longer-useable energy as entropy.

All economic activity comes from harnessing available energy in nature—in material, liquid, or gaseous form—and converting it into goods and services. At every step in the production, storage, and distribution process, energy is used to transform nature's resources into finished goods and services. Whatever energy is embedded in the product or service is at the expense of energy used and lost—the entropic bill—in moving the economic activity along the value chain. Eventually, the goods we produce are consumed, discarded, and recycled back into nature, again, with an increase in entropy. Engineers and chemists point out that in regard to economic activity there is never a net energy gain but always a loss in available energy in the process of converting nature's resources into economic value. The only question is: When does the bill come due?

The entropic bill for the First and Second Industrial Revolutions has arrived. The accumulation in carbon dioxide emissions in the atmosphere from burning massive amounts of

fossil fuels has given rise to climate change and the wholesale destruction of the Earth's biosphere, throwing the existing economic model into question. The field of economics, by and large, has yet to confront the fact that economic activity is conditioned by the laws of thermodynamics.

Until very recently, economists were content to measure productivity by two factors: machine capital and labor performance. But when Robert Solow—who won the Nobel Prize in economics in 1987 for his growth theory—tracked the Industrial Age, he found that machine capital and labor performance only accounted for approximately 14 percent of all of the economic growth, raising the question of what was responsible for the other 86 percent. This mystery led economist Moses Abramovitz, former president of the American Economic Association, to admit what other economists were afraid to acknowledge—that the other 86 percent is a “measure of our ignorance.”

Over the past 25 years, a number of analysts, including physicist Reiner Kümmel of the University of Würzburg, Germany, and economist Robert Ayres at INSEAD business school in Fontainebleau, France, have gone back and retraced the economic growth of the industrial period using a three-factor analysis of machine capital, labor performance, and thermodynamic efficiency of energy use. They found that it is “the increasing thermodynamic efficiency with which energy and raw materials are converted into useful work” that accounts for most of the rest of the gains in productivity and growth in industrial economies. In other words, “energy” is the missing factor.

A deeper look into the First and Second Industrial Revolutions reveals that the leaps in productivity and growth were made possible by the communication/energy/transportation matrix and accompanying infrastructure that comprised the general-purpose technology platform that firms connected to. For example, Henry Ford could not have enjoyed the dramatic advances in efficiency and productivity brought on by electrical power tools on the factory floor without an electricity grid. Nor could businesses reap the efficiencies and productivity gains of large, vertically integrated operations without the telegraph and, later, the telephone providing them with instant communication, both upstream to suppliers and downstream to distributors, as well as instant access to chains of command in their internal and external operations. Nor could businesses significantly reduce their logistics costs without a fully built-out road system across national markets. Likewise, the electricity grid, telecommunications networks, and cars, buses, and truck running on a national road system were all powered by fossil fuel energy, which required a vertically integrated energy infrastructure to move the resource from the wellhead to the refineries and gasoline stations.

The general-purpose technology infrastructure of the Second Industrial Revolution provided the productive potential for a dramatic increase in growth in the twentieth century. Between 1900 and 1929, the United States built out an incipient Second Industrial Revolution infrastructure—the electricity grid, telecommunications network, road system, oil and gas pipelines, water and sewer systems, and public school systems. The Depression and World War II slowed the effort, but after the war the laying down of the interstate highway system and the completion of a nationwide electricity grid and telecommunications network provided a mature, fully integrated infrastructure. The Second Industrial Revolution infrastructure advanced productivity across every industry, from automobile production to suburban commercial and residential building developments along the interstate highway exits.

During the period from 1900 to 1980 in the United States, aggregate energy efficiency—the ratio of useful to potential physical work that can be extracted from materials—steadily rose along with the development of the nation’s infrastructure, from 2.48 percent to 12.3 percent. The aggregate energy efficiency leveled off in the late 1990s at around 13 percent with the completion of the Second Industrial Revolution infrastructure. Despite a significant increase in efficiency, which gave the United States extraordinary productivity and growth, nearly 87 percent of the energy we used in the Second Industrial Revolution was wasted during transmission.

Even if we were to upgrade the Second Industrial Revolution infrastructure, it’s unlikely to have any measurable effect on efficiency, productivity, and growth. Fossil fuel energies have matured and are becoming more expensive to bring to market. And the technologies designed and engineered to run on these energies, like the internal-combustion engine and the centralized electricity grid, have exhausted their productivity, with little potential left to exploit.

Needless to say, 100 percent thermodynamic efficiency is impossible. New studies, however, including one conducted by my global consulting group, show that with the shift to a Third Industrial Revolution infrastructure, it is conceivable to increase aggregate energy efficiency to 40 percent or more in the next 40 years, amounting to a dramatic increase in productivity beyond what the economy experienced in the twentieth century.

Cisco systems forecasts that by 2022, the Internet of Things will generate \$14.4 trillion in cost savings and revenue. A General Electric study published in November 2012 concludes that the efficiency gains and productivity advances induced by a smart industrial Internet could resound across virtually every economic sector by 2025, impacting “approximately one half of the global economy.”

The Rise of the Sharing Economy

While the developing digital infrastructure is making the traditional capitalist market more productive and competitive, it is also driving the meteoric growth of the Sharing Economy. In the Sharing Economy, social capital is as vital as finance capital, access is as important as ownership, sustainability supersedes consumerism, cooperation is as crucial as competition, and “exchange value” in the capitalist marketplace is increasingly supplemented by “shareable value” on the Collaborative Commons. Millions of people are already transferring bits and pieces of their economic life to the Sharing Economy. Prosumers are not only producing and sharing their own information, news, knowledge, entertainment, green energy, transportation, and 3Dprinted products in the Sharing Economy at near zero marginal cost. Forty percent of the US population is actively engaged in sharing homes, toys, tools, and countless other items. For example, millions of apartment dwellers and home owners are sharing their living quarters with millions of travelers, at near zero marginal cost, using online services like Airbnb and Couchsurfing. In New York City alone, Airbnb’s 416,000 guests who stayed in houses and apartments between 2012 and 2013 cost the New York hotel industry 1 million lost room nights.

Recent surveys underscore the broad economic potential of the Sharing Economy. A comprehensive study found that 62 percent of Gen Xers and Millennials are attracted to the notion of sharing goods, services, and experiences in Collaborative Commons. These two generations differ significantly from the baby boomers and World War II generation in favoring

access over ownership. When asked to rank the advantages of a Sharing Economy, respondents to the survey listed saving money at the top of the list, followed by impact on the environment, lifestyle flexibility, the practicality of sharing, and easy access to goods and services. As for the emotional benefits, respondents ranked generosity first, followed by a feeling of being a valued part of a community, being smart, being more responsible, and being a part of a movement.

How likely is it that the Sharing Economy will play an ever larger role in the economic life of society in the coming decades? According to an opinion survey conducted by Latitude Research, “75% of respondents predicted their sharing of physical objects and spaces will increase in the next five years.” Many industry analysts agree with these optimistic forecasts. *Time* magazine declared collaborative consumption to be one of its “10 ideas that will change the world.”

Addressing Climate Change

The German “Energy Transition Dialogue” Summit comes just eight months before the United Nations Climate Change Conference in December in Paris. The UN Climate Conference revolves around a series of benchmarks—an increase in energy efficiency, a reduction of CO₂ and other global warming gases, and an increase in renewable energies. However, without an economic vision and development plan for transitioning participating nations into a post-carbon era, governments are reluctant to commit their countries to these benchmarks in a period where GDP is slowing, productivity is waning, and unemployment remains high. They are far more likely to perceive the benchmarks as punishments that will only serve to further constrict their economies. The nations of the world would be far more likely to make commitments to the UN Climate Conference benchmarks if pegged to a new economic paradigm that can increase productivity, create new economic opportunities, and put people back to work, ensuring a more vibrant and sustainable society, while transitioning their economies out of carbon-based energies and technologies and into renewable energies. That vision is now taking hold in Germany and other countries.

In a fully-digitalized economy, extreme productivity, triggered by the optimization of aggregate energy efficiency in the managing, powering, and moving of economic activity, decreases the amount of information, energy, material resources, labor, and logistics necessary to produce, store, distribute, consume, and recycle economic goods and services toward near zero marginal cost. The partial shift from ownership to access in a growing Sharing Economy also means more people are sharing fewer items—the birth of the circular economy—significantly reducing the number of new products sold, resulting in fewer resources being used up and less global warming gases being emitted into the earth’s atmosphere. In other words, the headlong push to a near zero marginal cost society and the sharing of nearly free green energy and redistributed goods and services in the Sharing Economy is the most ecologically efficient economy achievable. The drive to near zero marginal cost is the ultimate benchmark for establishing a sustainable future for the human race on earth. The Third Industrial Revolution paradigm transforms the UN Climate Conference benchmarks from perceived punitive measures to goalposts on the journey to a more prosperous and sustainable post-carbon economic era.

Beyond Germany: Spurring New Business Opportunities and Mass Employment in an Emerging EU Digital Economy

The European Union is potentially the largest internal market in the world, with 500 million consumers, and an additional 500 million consumers in its associated partnership regions, stretching into the Mediterranean and North Africa. The build-out of an Internet of Things platform for a Third Industrial Revolution, connecting Europe and its partnership regions in a single integrated economic space, will allow business enterprises and prosumers to produce and distribute information, renewable energy, 3D printed products, and a wide range of other products and services at low marginal cost in the conventional marketplace, or at near zero marginal cost in the Sharing Economy, with untold economic benefits for society.

Erecting the Internet of Things infrastructure for a digital Third Industrial Revolution economy will require a significant investment of public and private funds, just as was the case in the first and second industrial revolutions. European investment on infrastructure-related projects totaled \$741 billion in 2012, much of it to shore up a second industrial revolution general purpose technology platform that is outmoded, and whose productivity potential has long since been reached. If just twenty five percent of these funds were redirected and earmarked in every region of the European Union to assemble an Internet of Things infrastructure, the Digital Union could be phased in between now and 2040.

The EU communication network will have to be upgraded with the inclusion of universal broadband and free Wi-Fi. The energy infrastructure will need to be reconfigured from fossil fuels and nuclear power to renewable energies. Millions of buildings will need to be retrofitted and equipped with renewable energy harvesting installations, and converted into micro power plants. Hydrogen and other storage technologies will have to be built into every layer of the infrastructure to secure intermittent renewable energy. The electricity grid of the European Union will have to be transformed into a smart digital Energy Internet to accommodate the flow of energy produced by millions of green micro power plants. The transportation and logistics sector will have to be digitalized and transformed into an automated GPS-guided driverless network running on smart roads and rail systems. The introduction of electric and fuel cell transportation will require millions of charging stations. Smart roads, equipped with millions of sensors, feeding real-time information on traffic flows and the movement of freight will also have to be installed.

The establishment of the Third Industrial Revolution Internet of Things infrastructure will necessitate the active engagement of virtually every commercial sector, quicken commercial innovations, promote small and medium sized enterprises, and employ millions of workers over the next forty years. The electric power companies, the telecommunication industry, the construction industry, the ICT sector, the electronics industry, transportation and logistics, the manufacturing sector, the life-sciences industry, and retail trade will all need to be brought into the process. Many of today's leading companies, as well as new commercial players, will help establish and manage the Internet of Things platform, allowing millions of others—small, medium, and large sized businesses, nonprofit enterprises, and prosumers—to produce and use renewable energy, transportation and logistics, and a panoply of other goods and services at low marginal cost in the exchange economy or at near zero marginal cost in the Sharing Economy.

Semi-skilled, skilled, professional, and knowledge workers will need to be employed across every region of Europe to construct and service the three Internets that make up the digital

platform of a Third Industrial Revolution economy. Transforming the European energy regime from fossil fuels and nuclear power to renewable energies is extremely labor intensive and will require millions of workers and spawn thousands of new businesses. Retrofitting and converting hundreds of millions of existing buildings into green micro-power plants and erecting millions of new positive micro-power buildings will likewise require tens of millions of workers and open up new entrepreneurial opportunities for energy-saving companies (ESCOs), smart-construction companies, and green-appliance producers. Installing hydrogen and other storage technologies across the entire economic infrastructure to manage the flow of green electricity will generate comparable mass employment and new businesses as well. The reconfiguration of the European electricity grid into an Energy Internet will generate millions of installation jobs and give birth to thousands of clean Web app start-up companies. And finally, rebooting the transport sector from the internal-combustion engine to electric and fuel-cell vehicles will necessitate the makeover of the nation's road system and fueling infrastructure. Installing millions of charging stations along roads and in every parking space is labor-intensive employment that will require a sizable workforce.

The massive build-out of the IoT infrastructure for a Third Industrial Revolution in every locality and region of Europe is going to spur an extended surge of mass wage and salaried labor that will run for forty years or more, spanning two generations. However, in the long run, the phase-in of a smart Digital Europe will ultimately result in a highly automated capitalist market economy by mid-century, operated by small professional and supervisory workforces using advanced analytics, algorithms, and artificial intelligence. The maturing of this smart infrastructure will lead to a migration of employment from an increasingly automated capitalist market to the growing social economy. While fewer human beings will be required to produce goods and services in the market economy, machine surrogates will play a smaller role in the nonprofit social economy for the evident reason that deep social engagement and the amassing of social capital is an inherently human enterprise. The social economy is a vast realm that includes education, charities, healthcare, child and senior care, stewardship of the environment, cultural activity and the arts, sports and entertainment, all of which require human-to-human engagement.

In dollar terms, the world of nonprofits is a powerful force. Nonprofit revenues grew at a robust rate of 41 percent—after adjusting for inflation—from 2000 to 2010, more than doubling the growth of gross domestic product, which increased by 16.4 percent during the same period. In 2012, the nonprofit sector in the United States accounted for 5.5 percent of G.D.P.

The nonprofit sphere is already the fastest-growing employment sector in many of the advanced industrial economies of the world. Aside from the millions of volunteers who freely give of their time, millions of others are actively employed. In the 42 countries surveyed by the Johns Hopkins University Center for Civil Society Studies, 56 million full-time workers are currently employed in the nonprofit sector. In some countries, employment in the nonprofit arena makes up more than 10 percent of the workforce. In the Netherlands, nonprofits account for 15.9 percent of paid employment. In Belgium, 13.1 percent of the workforce is in the nonprofit sector. In the United Kingdom, nonprofit employment represents 11 percent of the workforce, while in Ireland it's 10.9 percent. In the United States, nonprofit employment accounts for 9.2 percent of the workforce, and in Canada it's 12.3 percent. These percentages will likely rise steadily in the coming decades as employment switches from a highly automated market economy to a highly labor-intensive social economy.

Despite the dramatic growth curve in employment in the social economy, many economists look at it askance, with the rejoinder that the nonprofit sector is not an independent economic force but rather largely dependent on government-procurement contracts and private philanthropy. One could say the same about the enormous government procurements, subsidies, and incentives meted out to the private sector. But this aside, the Johns Hopkins study of 42 countries revealed that contrary to the view of many economists, approximately 50 percent of the aggregate revenue of the nonprofit sector already comes from fees for services, while government support accounts for only 36 percent of the revenues, and private philanthropy for only 14 percent. I expect that by midcentury, if not sooner, a majority of the employed around the world will be in the nonprofit sector, busily engaged in advancing the social economy, and purchasing at least some of their goods and services in a highly automated capitalist marketplace. John Maynard Keynes's futurist essay, written more than 80 years ago for his grandchildren, envisioned a world where machines have freed up human beings from toil in the marketplace to engage in deep cultural play in the social economy in the pursuit of more lofty and transcendent goals. It might prove to be his most accurate economic forecast.

The business at hand will be to provide both retraining for the existing workforce and the appropriate skill development for students coming into the labor market to ease the transition into the new job categories and business opportunities that come with a massive build-out of an Internet of Things infrastructure around the world. At the same time, students will need to be educated for the new professional skills that come with the job opportunities opening up in the social economy. Although a herculean effort will be required, the human race has shown itself capable of similar efforts in the past—particularly in the rapid shift from an agricultural to an industrial way of life between 1890 and 1940.

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In summary, the scale up of a smart digitalized Internet of Things infrastructure across the European Union, and its partnership regions, will generate new business opportunities in both the market economy and the Sharing Economy, dramatically increase productivity, employ millions of people, and create an ecologically oriented post-carbon society. The employment of millions of workers will also stimulate purchasing power and generate new business opportunities and additional employment to serve increased consumer demand. Infrastructure investment always creates a multiplier effect that reverberates across the economy as a whole.

The alternative, staying entrenched in the sunset of the Second Industrial Revolution, with fewer economic opportunities, a slowing of GDP, diminishing productivity, rising unemployment, and an ever-more polluted environment is unthinkable, and would set Europe on a long-term course of economic contraction and decline in the quality of life of its citizenry.

Lest skeptics think such a proposition utopian and unrealizable, China is already making it a reality in Asia. Premier Li Keqiang and the new leadership of China have embraced the Internet of Things platform and the Third Industrial Revolution economic vision. In September 2013, the Xinhua News Agency reported that Premier Li Keqiang had read *The Third Industrial Revolution* book that I authored with great interest and had instructed the National Development and Reform Commission and the Development Research Center of the State Council to read the book and follow up with a thorough study of the ideas and themes it puts forth. Subsequently, I

traveled to China for an official visit for two weeks in September 2013, where I met with Vice Premier Wang Yang and other key government officials to discuss the Chinese transition into a Third Industrial Revolution economy. Following my visit in September of 2013, the government of China announced an \$82 billion four year initial commitment to lay out a digital Energy Internet across China, so that millions of Chinese people and thousands of Chinese businesses can produce their own solar and wind generated green electricity and share surpluses with each other. Plans are also afoot to establish a Pan-Asian Internet of Things platform that will stretch across the continent, allowing 2.7 billion people, or nearly forty percent of the human race, to produce and share information goods, renewable energy, and transportation and logistics in a digitalized single market.

The European Union's plan to establish an Internet of Things platform for a digital economy opens up the prospect of joint collaboration with China in the creation of a digitalized integrated economic space across the Eurasian landmass to foster the transition into a Third Industrial Revolution and a post-carbon green civilization. In recent months, Chairman Xi and Premier Li of China have called for a new high-tech Eurasian Silk Road Economic Belt to connect the Eurasian land mass in a seamless integrated market from Shanghai to the Irish Sea. The build-out of a digitalized Internet of Things infrastructure across Eurasia could lead to a new age of deep collaboration, bringing much of the human family together for the first time in history.

We are on the cusp of a promising new economic era, with far reaching benefits for humankind. What's required now is global commitment to phase-in the Internet of Things platform across the world to facilitate the transition to a digitalized Zero Marginal Cost Society, if we are to avert catastrophic climate change and create a more just, humane, and ecologically sustainable society.

Jeremy Rifkin is the author of *The Zero Marginal Cost Society: The Internet of Things, the Collaborative Commons, and the Eclipse of Capitalism* and *The Third Industrial Revolution: How Lateral Power is Transforming Energy, the Economy, and the World*. Mr. Rifkin is an advisor to the European Union and to heads of state around the world, and president of the Foundation on Economic Trends in Washington, DC.