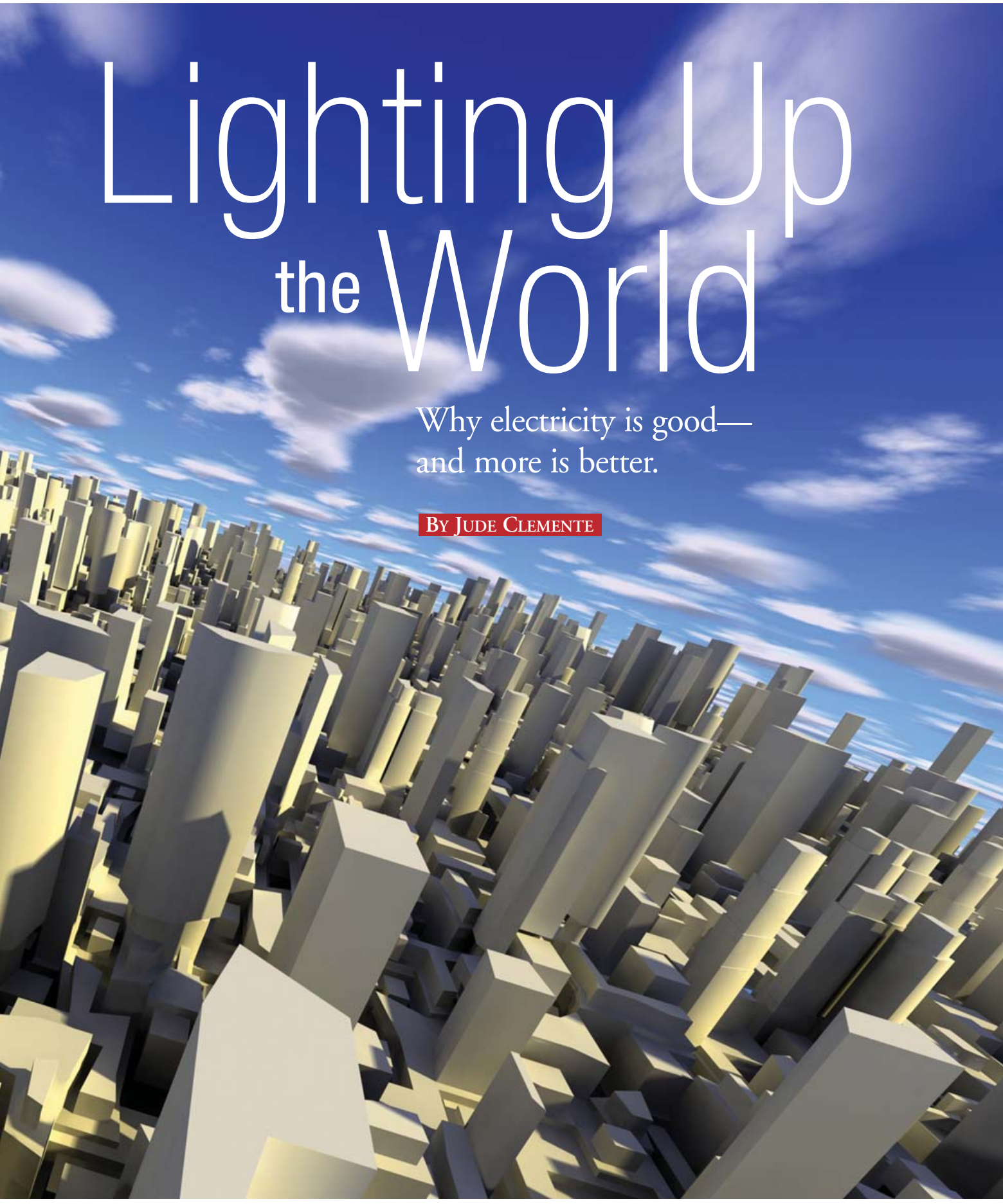

Lighting Up the World

Why electricity is good—and more is better.

By Jude Clemente

"Electricity ushered in a transformation of American society at the end of the 19th Century. Suddenly, the backbreaking work that consumed dawn to dusk for most Americans was alleviated by electric motors, dynamos, and generators. Electric household appliances made it possible to heat homes, cook food, store meat and perishable items, and wash clothes without the drudgery and fear of disease that had haunted previous generations."—Ohio Department of Public Utilities, 2009[1]

As the *sine qua non* of modern society, electricity is essential to gains in quality of life, economic well-being, and a cleaner environment. The demand for power will ascend accordingly as the modernization process continues amid global population and economic expansion. The International Energy Agency (IEA) reports that the world is on pace to consume over 38,400 terawatt hours (TWh) in 2030, compared to 21,160 TWh in 2010 and an incremental increase almost four times greater than what the United States will consume this year.[2] Unfortunately, this massive 82 percent increase in power generation will not nearly be enough. The IEA also projects that 1.2 billion people will still lack electricity in 2030, a "shameful and unacceptable" 14 percent reduction from today.[3] Conservation and efficiency programs, while vital to a modern economy, have distinct limitations. In the 2009 study, *Assessment of Achievable Potential from Energy Efficiency and Demand Response Programs in the U.S.* (2010-2030), the Electric Power Research Institute (EPRI) found that domestic electricity consumption will grow by 0.68 percent per year even under "conditions ideally conducive to energy efficiency programs."[4]

Despite the recognition that electricity is the cornerstone of a modern industrial society, the United States confronts a policy gridlock arising from internecine conflicts of competing groups determined to stop the general development of particular technologies (*e.g.*, coal, nuclear) or the specific development of particular projects (*e.g.*, wind, hydro, gas pipelines). To be sure, most of these groups give lip service to the importance of electricity, but they frequently fail to mention the crucial advantages of a diversified electric power system—where the whole is greater than the sum of its parts. At the same time, there is a visible but insidious movement to raise the price of energy to reduce consumption, propel progress toward meeting climate change goals, or fit a social agenda promoting lifestyle change. According to Carl Pope, then executive director of the Sierra Club:

> "Indeed, the widespread implication that the key policy needed to reduce carbon dioxide emissions is a price on carbon does reinforce the notion that the most important things needed to solve the climate crisis are higher energy prices and lower consumption."[5]

The assertion that raising energy prices to reduce demand is a societal positive, however, runs counter to experience. Higher prices have adverse socioeconomic and public welfare impacts, notably a disproportionate effect on low income households. Econometric studies have shown that rising electricity costs contributed to the slowdown in productivity growth during the 1970s and early 1980s.[6] For U.S. states, higher electricity prices harm businesses and families and erode the ability of domestic firms to compete in their increasingly competitive global industries. In the developing world, however, high electricity prices wreak the most havoc since the people have almost no capacity to absorb them. In short, the world needs more electricity use, not less, as the advancement of electrotechnologies will continue to enhance public health and welfare through greater efficiency and a cleaner environment.

Higher electricity prices have adverse impacts on public welfare, with disproportionate effects on low-income households.

Cheap Electricity is Better

When he was governor of the State of New York in 1930, Franklin D. Roosevelt said:

> "[H]igh rates, of course, bear hard on the individual. But from a social standpoint they are chiefly to be regretted because they restrict the use of electricity. Rate schedules should be so adjusted as to induce the freest possible use of electricity both in the home and on the farm."[7]

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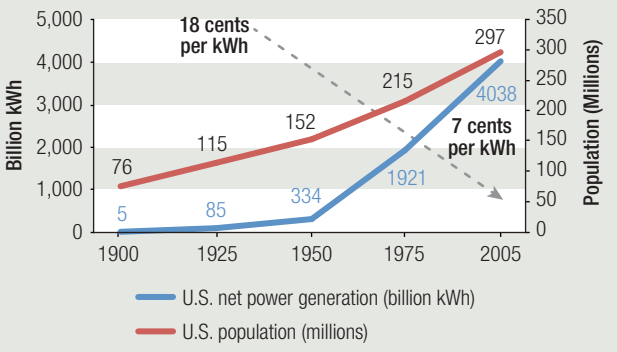
Fig. 1 **More People, Using More Electricity, at Lower Cost**



Source: Energy Information Administration, U.S. Census Bureau, and Wagner

In 2002, the National Academy of Engineering identified societal electrification as the "greatest engineering achievement" of the 20th Century—a century that saw a global population increase of over 4 billion people, the rise of the metropolis, unprecedented improvements in diet and health, and the emergence of a vast system of transportation and electronic communication.[8] Access to electricity brought about a sea change to the American quality of life, ranging from childhood survival to clean drinking water to literacy. The socioeconomic benefits of the Rural Electrification Act of 1936 alone demonstrate the scope of electricity's importance to living a longer and better life. Arguments that states, such as California, have grown their economy and flattened electricity consumption through efficiency policies are largely rhetorical. Regression analyses confirm that approximately 80 percent of California's lower per capita use of electricity is due to unique characteristics like higher prices, milder weather, and smaller homes with more people.[9]

In addition to providing the basic services for human existence, electricity offers a key opportunity to increase productivity. Consider the evolution from kerosene to electric lighting, which reduces costs by over 80 percent and fuel usage by nearly 90 percent.[10] As the price of lighting declines, more illumination services are consumed, which leads to a direct increase in economic welfare. Cheaper illumination allows household members to devote time at night to improve their literacy and education capacity. Such gains in productivity lead to an additional increase in the demand for lighting that offers even more economic output to the society. Households can divert hours once spent gathering fuel to working in the marketplace, which generates more income for the home and labor services for the economy. Efficient electricity networks generate powerful economic externalities by lowering the costs of telecommunications and information, which in turn generate numerous productivity enhancements. These outcomes contribute to an overall increase in quality of life, especially better health, less drudgery, more leisure, and greater communication.

Both the literature and real world are replete with examples of how socioeconomic progress hinges upon ever-increasing supplies of affordable and reliable electric power, where agrarian communities are transformed into modern industrial societies. This evolution, driven by the accumulation of income and wealth, eliminates many contagious diseases, reduces child mortality, and lengthens life expectancy—a virtuous cycle has been demonstrated over and over again for well over a century in dozens of countries around the world. The emergence from poverty begins as countries develop transportation systems based upon petroleum and electricity networks typically based upon coal. These technologies are able to achieve massive economies of scale that provide large amounts of energy at low cost. Abundant and reliable supplies of energy spur technological change and productivity growth, thereby substantially improving the living standards of the people.

Arguments that the small market shares of renewable energy systems are the result of market distortions, such as the absence of pricing for environmental externalities, ignore the reality: the IEA's latest *450 Scenario* (2010), which optimistically assumes that "policy action is taken to limit the long-term concentration of greenhouse gases in the atmosphere to 450 parts per million of CO_2-equivalent," projects fossil fuels and nuclear power will still generate 70 percent of U.S. electricity in 2030.[11] Wind and solar energy, for instance, are inconveniently intermittent and considerably more expensive, not yet capable of utilizing the economies of scale that conventional energy enjoys. To promote these uncompetitive technologies, governments use subsidies and production mandates like the so-called "renewable portfolio standard" (RPS). These policies not only swell government spending and bureaucracy but also impose hidden efficiency costs on the economy that silently erode our standard of living. This helps explain why two leading U.S. authorities on electricity, Jay Apt (Carnegie Mellon University) and Robert Michaels (California State University, Fullerton), have publicly opposed a possible federal RPS, known as a "renewable energy standard."[12]

Living Longer and Better

In 1936, the year of the *Rural Electrification Act*, an article in *The New York Times* stated, "Nothing in modern life so raises the standard of living of high- and low-income groups as the use of electricity."[13]

The rise in the standard of living in the United States over the past century has been the envy of the world. Society after society has tried to emulate the tremendous progress that we have made in health, education, productivity, environmental improvement, and science and technology. The foundation of this leap forward is the ever increasing access to reliable and affordable electricity. The rapid expansion of the U.S. population was closely paralleled with the generation of electricity that

the average American could afford to buy (*see Figure 1*).

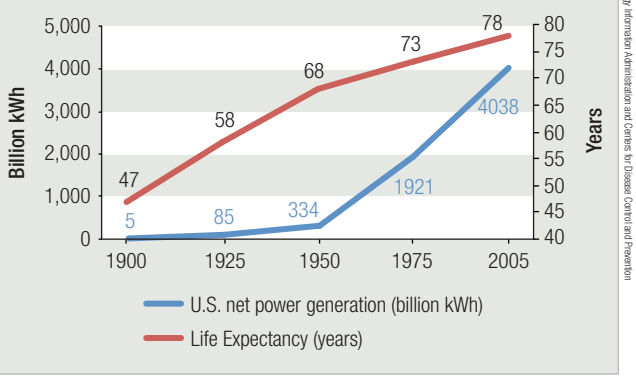
Additionally, electrification has increased the average human life span. Brenner's work in the *International Journal of Epidemiology* (2005) clearly demonstrates the link between affordable energy, economic growth, and declining mortality over the course of the 20th Century: "It is now among the firmest of epidemiological findings, across industrialized societies, that socioeconomic status is inversely related to health status."[14] Greater access to electricity has meant more food, cleaner water, new medicines, safer work settings, and more control of the environment through heating and eventually air conditioning—all hallmarks of industrialization and modernization made possible by electric power. Accordingly, Americans have experienced a dramatic increase in life expectancy (*see Figure 2*).

One of the principal reasons that life expectancy soared over the last century was that people were much more likely to survive childhood. Survival during the first year of life was particularly important and remains a direct reflection of the technological level of a society (*see Figure 3*). As Zakir and Wunnava (1999) note in *Applied Economics Letters*: "Infant mortality rates serve as excellent health status indicators across and within economies … and are associated with the well-being of a population."[15] From 1900 to 1936, Cutler and Miller (2005) report in *Demography* that clean water was responsible for 74 percent of the reduction in infant mortality and 62 percent of the reduction in child mortality in a study of 13 U.S. cities.[16]

The impact of electricity access on sanitation and cleaner water is noteworthy. In 1940, nearly one-half of U.S. homes lacked complete plumbing facilities and more than one-third had no flush toilet.[17] By 1960, electricity consumption had greatly increased, power was widely available, and 84 percent of the homes had complete plumbing facilities and 90 percent had a flush toilet (CDC, 2009). The better sanitation from electricity had a marked positive effect on waterborne diseases (*see Figure 5*). From 1900 to 1936, Cutler and Miller (2005) report that clean water was responsible for about 43 percent of the total mortality decline in 13 U.S. cities. On average, water filtration reduced typhoid fever deaths by 46 percent—nearly eradicating the disease in the United States by 1936. Today, a lack of electricity devastates by creating a breakdown in the critical vaccine "cold chain."

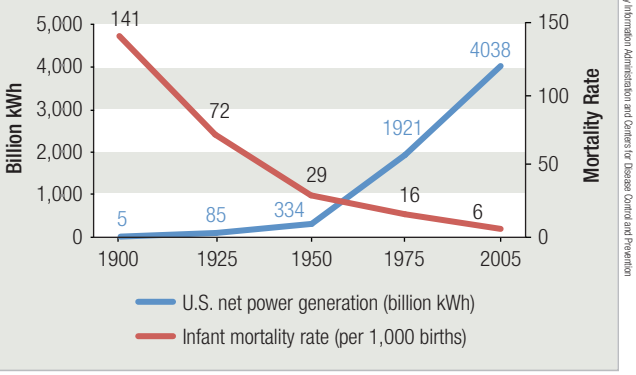
Additionally, electricity has improved quality of life. Kurt Yeager, former chief executive officer of EPRI, states in the *Encyclopedia of Energy Engineering and Technology* (2007) that "electricity is more than a form of commoditized energy; it is the underpinning of the modern quality of life, and the nation's indispensable engine of prosperity and growth."[18] The integration of accessible, reliable, and affordable electricity into the social structure had a significant positive impact. Americans truly do live better with more electricity—and they make more money. There has been a remarkably stable linear relationship between electricity consumption and GDP over the decades (*see Figure 4*).[19] In fact, Lacko (1999) observed a near one to one ratio in a number of different countries.[20]

Fig. 2 Electricity Generation and Life Expectancy



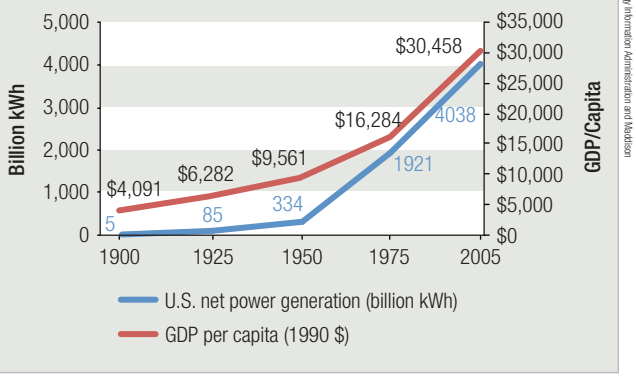
Source: Energy Information Administration and Centers for Disease Control and Prevention

Fig. 3 Electricity Generation and Infant Mortality



Source: Energy Information Administration and Centers for Disease Control and Prevention

Fig. 4 Electricity Generation and GDP per Capita

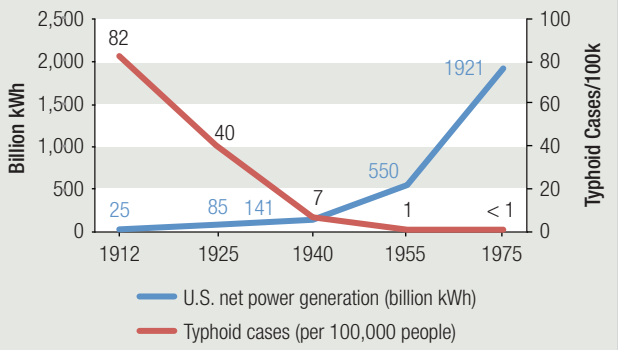


Source: Energy Information Administration and Maddison

TVA: Transforming Rural America

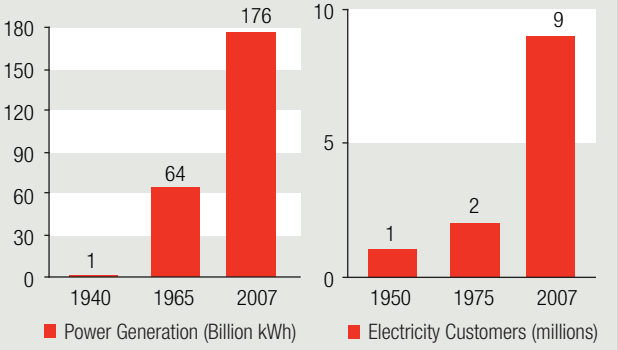
The Tennessee Valley Authority provides a vivid example of how electrification has improved life in rural communities. "The general impression of the whole area affected by the TVA is that a transformation in rural life has been achieved," wrote E. George Payne in the *Journal of Educational Sociology* (1946).[21]

Fig. 5 Electricity = Cleaner Water, Less Disease



Source: Energy Information Administration and Cutler and Miller.

Fig. 6 The Growth of TVA



Source: Tennessee Valley Authority and *The New York Times* from ProQuest Historical Newspapers (1851-2007).

Although the majority of Americans living in large towns and cities had electricity by the early 1930s, less than 10 percent of those residing in small towns and farms had power.[22] President Franklin Roosevelt strongly believed that all citizens deserved equal access to the miracle of electricity, so the *Rural Electrification Act* was passed in 1936. At that time, perhaps the most intense pocket of poverty in rural America was concentrated in the southern states of Tennessee, Virginia, North Carolina, Alabama, Kentucky, Georgia, and Mississippi. Overall per capita income in the region was only 40 percent of the national average, and farm income was even lower—barely one-third the take of farmers in other parts of the nation.[23] In 1933, the average annual income for a farm family in what would become the Tennessee Valley Authority (TVA) region was just $168, as only 3 percent of the farms had power.[24] This made sanitation an ongoing problem and malaria more common. A lack of educational opportunities plagued communities and kept illiteracy rates high.

Operating with the power of government but the flexibility of private industry, TVA was a federal agency established under President Roosevelt's New Deal to bring electricity, flood control, and economic stability to the Tennessee River Valley during the ravages of the Great Depression in the 1930s. TVA began to provide inexpensive electricity to rural residents of the Valley in 1934. Through the Authority, farmers throughout the South experienced firsthand the benefits of using electricity to easily grind corn, milk cows, and perform other daily chores. Farm wives saw the benefits of electric water pumps, washing machines, irons, lights, and radios. TVA spurred greater demand in rural areas for cheaper electricity and established the Electric Home and Farm Authority to help farmers purchase electric appliances like stoves and washing machines.

Farm families were quickly astonished how much easier and more enjoyable these electrical gadgets made their lives. By 1936, *The New York Times* published an entire article on the topic, titled "New Era of Power Revolutionizes Life in the Tennessee Valley."[25] By 1940, a Tennessee farmer had discovered that the "greatest thing on earth is to have the love of God in your heart, and the next greatest thing is to have electricity in your house."[26] The social, economic, and psychological changes for rural America were far reaching indeed; the number of rural homes in the United States with electricity boomed from less than one in 10 in 1936, to one in four in 1939, to nine in 10 in 1950.[27] In TVA's first 15 years alone, per-capita income within the Valley climbed from 40 percent of the national average to nearly 60 percent.[28]

TVA was granted permission in the 1950s to issue bonds and became self-sufficient enough to pay its own way. By the 1960s, the region's electricity prices were the lowest in the U.S., and the rural southeast, probably the country's worst economic rural area just a generation prior, was electrified, highly productive, and relatively free from the devastation caused by flooding. As realized by Knop (1979), "after 40 years TVA's main goals have been achieved," and average household electricity use within the Valley had increased 15-fold and per capita income had surpassed the national average.[29] TVA is a prime example of material progress through more energy usage—and remains a model for the developing world (*see Figure 6*).

Emancipation of Women

George Norris, U.S. Senator from Nebraska, co-sponsor of the Rural Electrification Act, said in 1936:

> "I had seen first-hand the grim drudgery and grind which had been the common lot of eight generations of American farm women… I could close my eyes and recall the innumerable scenes of the harvest and the unending punishing tasks performed by hundreds of thousands of women, growing old prematurely; dying before their time… Why shouldn't I have been interested in the emancipation of hundreds of thousands of farm women?"[30]

In 1900, surveys indicated that the typical American housewife spent 44 hours a week cooking, cleaning, and doing laundry.[31] Food preparation could consume an entire day as meals were usually prepared from scratch. Wood had to be cut and

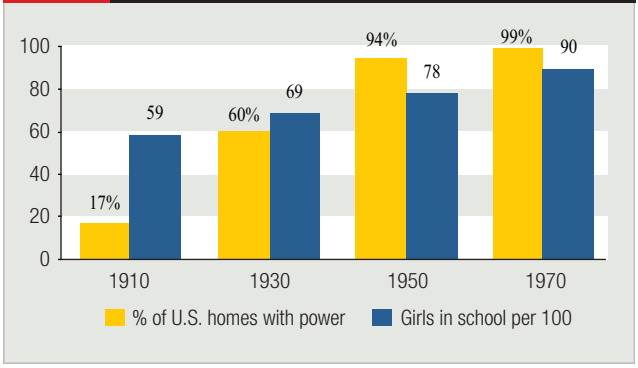
coal had to be hauled. Fuel stoves had to be cleaned and virtually no houses had indoor plumbing. With limited refrigeration, daily trips to the market were required. Even bearing water was a daily backbreaking chore. "You see how round shouldered I am? Well, that's from hauling water. I was round shouldered like this well before my time," said a farm woman from Tennessee at the time.[32]

In 1912, Thomas Edison predicted to *Good Housekeeping Magazine* that the "housewife of the future will be neither a slave nor a drudge; she will be rather a domestic engineer than a domestic laborer, with the greatest of all handmaidens, electricity, at her service. This will so revolutionize the woman's world that a large portion of the aggregate of woman's energy will be conserved for use in broader, more constructive fields."[33] Over the next few decades, a full range of electricity-based appliances, from vacuum cleaners and refrigerators to washing machines and the ever sought-after electric lights, became available in rural homes. By 1936, *The New York Times* (Ostrolenk) noticed that the "American housewife has taken to electricity with an alacrity that even the depression could not stop," and the Federal Power Commission affirmed that electrical gadgets had become as "essential in our daily lives as the bread we eat and the water we drink."

In *Engines of Liberation*, Greenwood et al. (2002) note that with the rise of electricity these labor-saving electrotechnologies provided nothing less than a household transformation that was, in many ways, socially equivalent to the industrial revolution. Before the onset of electricity, the vast majority of women worked at home. By the end of the 20th Century, however, most would work in the open market. The technological progress engendered by the availability of electricity to the household sector played a major role in liberating women from the home. For example, female education was allowed to become a priority (*see Figure 7*). Regardless of any shift in societal attitudes, these drastic changes would not have been possible without electricity. Paraphrasing Greenwood's group, while sociology may have supplied the fuel for the women's movement, the spark that ignited it came from electricity and the ability of women to spend more time outside the home.

Indeed, greater electricity access quickly opens new doors for women, today a particularly vulnerable segment of the global population. Although women constitute 50 percent of the world's population, they account for 70 percent of the poor.[34] There is a "feminization of poverty" that will be impossible to resolve without greater access to electricity and other forms of energy. Elizabeth Cecelski of *Energia*, an international network on gender and sustainable energy, says that there is a "gender bias in rural energy poverty, too, because the main source of energy in poor rural households is not biomass—it is women's labor."[35] In developing countries, the constant scour for energy is mostly

Fig. 7 Electricity at Home = More Girls in School



Source: National Association of Secondary School Principals and *The New York Times* from Proquest Historical Newspapers (1851 - 2007)

reserved for women and their children. Daily household chores—gathering wood, carrying water, and cooking—are all either eliminated or made easier, safer, and healthier with the availability of electricity.

The Importance of Electrotechnologies

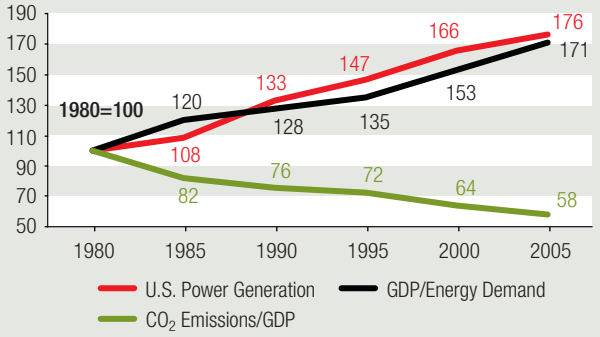
EPRI Fellow Clark Gellings wrote in a 2007 study:

> "Tapping the energy-saving potential of electricity is an opportunity custom-made for today, as the issues of a sustainable energy future and a clean and safe environment become more urgent. In addition to addressing these needs, electrotechnologies offer a host of non-energy benefits, including improved manufacturing precision and control, enhanced product quality, increased worker productivity, and reduced environmental impacts. While efficient electrotechnologies are used throughout industry today, the potential for broader application remains, as does the potential for greater energy-efficient processes."[36]

When it comes to reducing demand and GHG emissions, Nobuo Tanaka, executive director of the IEA, calls energy efficiency "the 'low hanging fruit' with huge potential."[37] The efficiency with which fossil fuels and renewable energies can be utilized is quite low in most applications and, for reasons of fundamental physics, inherently limited. For example, the best coal-fired plants convert only around 46 percent of input into electricity, and some gas turbines operate with capacity factors between 5 and 25 percent.[38] The internal combustion engine (ICE), meanwhile, converts just 20 percent of the energy stored in gasoline into useful motion, and wind and solar systems having capacity factors of 35 percent or so are considered advanced.[39] In contrast, the efficiency with which electricity can be used more than offsets the inefficiency of making it. Electricity is a very high quality form of energy and can be converted to mechanical energy (in running electric motors), thermal energy (in heating water), and electromagnetic radiation (in radio broadcast) with little loss of energy while changing form. Electric motors, for instance, convert over 90 percent of elec-

Fig. 8 More Electricity = More Efficiency, Less CO2

CO_2 expressed as intensity of emissions as a factor of gross domestic product.



Source: Energy Information Administration, U.S. Department of Agriculture, BP

tricity into useful motion.[40]

Electrotechnologies are systems and equipment that use electricity to produce and process consumer goods. From refrigerators to vacuum cleaners to laptop computers, electrotechnologies are all around us. Electrotechnologies are more efficient than their fuel-burning counterparts and, unlike standard fuels, have no waste products at the point of use. No smoke, ash, combustion gas, noise, or odor. In the United States, the evidence that using electricity increases energy efficiency can be seen in overall national trends (*see Figure 8*). Importantly, if using fuels to generate electricity was so wasteful, as some have proposed, the magnitude of the electric sector's fuel consumption (39 percent of our total energy demand) would be driving down U.S. energy efficiency.[41] Instead, the exact opposite is occurring. More economic output is being supported by decreasing amounts of primary fuels. From 1980 to 2005, the United States saw a 76 percent increase in power generation but a 71 percent rise in overall energy efficiency—and a 42 percent decrease in the CO2 intensity of the economy.[42] And there are at least three main areas in which even more progress in efficiency and productivity is achievable with the continuing evolution of electrotechnologies:

■ *Lighting:* A study by the UN Environment Program and Global Environment Facility (2010) found that replacing incandescent lighting with more efficient electrotechnologies could save the United States $9 billion a year and avoid roughly 50 million tons of CO_2 emissions annually, the equivalent of removing 11 million vehicles from the road.[43] Compact fluorescent lamps use two-thirds less energy than conventional light bulbs, while lasting up to 10 times longer.[44]

■ *Transportation:* According to Keulenaer and Grawe (2006), the use of high-speed electric trains instead of air transport reduces primary energy consumption per passenger-kilometer by a factor of three and CO_2 emissions by a factor of four.[45] Electric vehicles are twice as efficient as ICE vehicles, and using electric trains instead of diesel trains decreases primary energy use by a factor of two and CO_2 emissions by a factor of four.

■ *Industry:* The U.S. Department of Energy (2011) notes that the annual fuel utilization efficiency (AFUE) rating for an all-electric furnace or boiler is between 95 and 100 percent.[46] By comparison, mid- and low-efficiency heating systems have AFUE ratings of 68 to 72 percent and 80 to 83 percent respectively.

Electrifying the Planet

Electric power has resulted in a sea change in the American quality of life, and increases in electricity consumption are critical to economic development, energy security, and climate change mitigation. Electricity, as an especially high grade of energy, facilitates technological advancement, and in turn stimulates the economy by increasing productivity. The United States is a growing country and base load capacity derived from fossil fuels and nuclear power will be sorely needed in the decades ahead—these sources generate over 90 percent of our electricity. In fact, as a testament to their competitive advantage, the high reliability of coal and nuclear is unique in that their share of total U.S. generation far exceeds their share of capacity, 58 percent and 90 percent in 2008 respectively.[47] Going forward, the developing nations will need full access to the very same diverse range of fuels that has empowered their industrialized counterparts to raise the living standards for, and extend the lives of, billions of people.

Mainstream generation continues to be the least expensive and most scalable electricity.

For at least the foreseeable future, mainstream generation technologies will continue to be the least expensive and most scalable sources of electricity in virtually every country in the world. Support for cleaner energy like wind and solar power might one day lead to cheap electricity—but not yet, which is why their subsidies per unit of production have been nearly 70 times higher than gas and coal, for example.[48] Today, cheap electricity is the driving force behind the economic miracles unfolding in both China and India. Pasternak (2000) found that a per-capita annual consumption rate of at least 4,000 kWh of electricity is required for a nation to reach a significant Human Development Index of 0.9.[49] Electricity poverty is thus a global blight: well over four billion people, at least 60 percent of the world's population, use fewer than 2,350 kWh per year, or only one-third as many as a typical resident of the European Union.[50] The *Copenhagen Accord 2009* claimed the IEA-reported $36 billion per year until 2030 investment needed for universal access to electricity as a "first and overriding" priority.[51]

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