RISKY BUSINESS

APPENDIX 4:
A-4 Case Studies

From Risk to Return: Investing in a Clean Energy Economy

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Bottom Line Benefits for Cities Going Green

Georgetown, Texas, never set out to be one of the first municipalities in the U.S. to power itself entirely with renewable electricity. Instead, says Jim Briggs, Georgetown's general manager of utilities and assistant city manager, the goal has always been improving the bottom line for the city's businesses and 70,000 residents. "Our objective has always been to provide our customers with the most cost-effective, least risky and lowest-cost product that I can," he says.

The story begins in the mid-2000s, when Georgetown, a far more conservative city than Austin 28 miles to the south (it voted 60% Republican in 2012), began to worry that Briggs' objective was under threat. The city-owned utility had been buying wholesale power from the Lower Colorado River Authority in a long-term contract scheduled to end in 2016. About 60 percent of the city's electricity was generated from coal and 40 percent from natural gas. What concerned city officials was that the River Authority was planning to build a new coal plant in Texas. Not a good choice, they thought. With tighter rules on air pollution, water quality and greenhouse gas emissions virtually inevitable, they believed, a new coal plant would increase risks and costs for Georgetown. "We began to question whether this was in our best interest," says Briggs, who has been with the utility since 1986.

So Georgetown opted out of the new coal plant. It negotiated an exit to the contract four years early and planned a new strategy. "We felt a combination of natural gas, nuclear and some wind would hedge us against the regulations and keep us competitive on price," Briggs says. But when the contract with Lower Colorado River Authority ended in 2012, "we were still searching for a definitive resource for the future," Briggs says.

That's when a plunge in the prices of wind power from the Texas panhandle created a major opportunity to lock in low prices. In late 2013, the city signed a contract for electricity from a wind farm being built near Amarillo. "That was the first step in nailing down a big chunk of renewables," Briggs says. That project, which came on line in September 2015, brings the total wind power coming to Georgetown to about 150 MW —in a city where peak demand, which mainly occurs on August afternoons, is 145 MW (City of Georgetown Texas, n.d.).[1]

At the same time, the city realized that the perfect complement to wind, which typically blows strongest at night, was solar, which peaks in the afternoon. The problem in 2013, however, was that the wholesale price of solar power was then as high as 9 cents per kWh—too expensive for Georgetown, where retail customers pay roughly 9.5 cents per kWh. "When we plugged in the numbers, we couldn't make it work," Briggs says.

[1] City of Georgetown Texas, "Renewable Energy FAQs," available at https://gus.georgetown.org/renewable-energy-faqs/(last accessed August 2016).

Then the market worked in the city's favor again. The price of solar panels from China plummeted, and developers raced to build solar arrays before the investment tax credit was set to expire. With long-term contracts available in the range of 4 to 5 cents/kWh, "we knew we could pull the trigger," Briggs says. In early 2015, Georgetown signed up with SunEdison for 150 MW of solar power from a plant scheduled to be completed in West Texas in 2016. Georgetown expects that having more than twice as much capacity as the summer afternoon peak demand means that the city will be able to run entirely on renewable electricity almost all of the time—and usually with excess power to sell in the electricity markets.

"We didn't do this to save the world," Briggs says. The decision is simply a shrewd financial one. Not only can the city guarantee stable electricity prices for at least a decade, completely insulating itself from possible fossil fuel price shocks, it also expects to have excess power even during the hottest parts of the day when high state-wide demand can send spot prices soaring past 50 cents/kWh. Selling that extra power at high prices would bring a significant windfall, some of which the utility can pass on to customers in lower bills. Everyone benefits.

Georgetown is far from the only city or region seeing bottom line gains from going greener. Burlington, Vermont, is now completely powered with renewable electricity, using a mix of 45 percent hydro, 35 percent biomass and 20 percent wind (Ring, 2014).[2] Ken Nolan, Chief Operating Officer at Burlington Electric, calculates that eliminating fossil fuel use will save the city about $20 million dollars over the next two decades and help keep rates, which haven't increased since 2009, stable.

Meanwhile, Fort Collins, Colorado, accelerated the targets in its Climate Action Plan in early 2015 by planning to slash greenhouse gas emissions 80 percent by 2030—and to achieve zero net emissions by 2050 (City of Fort Colins, n.d.).[3] One of the key reasons: the chance to turn the city into a hub for a "climate economy," says Jackie Kozak Thiel, chief sustainability officer for the city. "These changes are actually going to provide economic opportunities."

Los Angeles has "already cut pollutants in our air by 66 percent despite growing our population by 1 million people," says Mayor Eric Garcetti, co-founder of the Mayors' National Climate Action Agenda. Now the city aims to cut greenhouse gas emissions by 45 percent by 2025 and 80 percent by 2050. "This is exciting progress for a city that is already on its way to having the largest pure electric vehicle fleet in the nation and that will be off coal within 10 years," Garcetti says.

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[2] Ring, W. 2014. "100% of power for Vermont city now renewable," September 15,, available at https://www.bostonglobe.com/metro/2014/09/14/vermont-milestone-green-energy-efforts/fsLHJl4eoqv6QoFNewRYBK/story.html.

[3] City of Fort Colins, "2014-2015 Municipal Sustainability Report," available at http://www.fcgov.com/climateprotection/(last accessed August 2016).

And in Iowa, the amount of the state's electricity generated from coal dropped from 70 percent in 2010 to 50 percent in 2014, according to Bloomberg New Energy Finance (BNEF). Wind power rose from 17 percent in May 2010 to 36 percent in May 2015 (with natural gas at just 3 percent). The effect on prices? Wholesale power prices were down 34-50 percent across Iowa in the first five months of 2015, compared to average prices over same period in the previous five years—another bottom line benefit from clean energy.

But the city that many people wouldn't expect to be a green leader is the world's oil and gas capital, Houston. In fact, Houston, through its agreement with Reliant Energy (The City of Houston, n.d.),[4] is now the number one purchaser of renewable electricity in the nation, at 623,000 MWh per year, or about half of the city's total demand (U.S. Environmental Protection Agency, 2014).[5] Former mayor Annise Parker put in place plans to bump that up to 75 percent or higher, thanks to projects like a 30 MW solar array in West Texas that the city approved in November 2015 that will provide electricity at 4.8 cents/kWh (Morris, 2015).[6] When she was mayor, Parker called buying renewable electricity "a triple win for Houstonians" because it spurs new investment, helps bring prices down, and offers a host of environmental benefits. However, "by far the most compelling argument is control over your costs," says William Fulton, director of the Kinder Institute for Urban Research at Rice University in Houston. The new solar project "costs only a tiny bit more than we pay today, but gives us 15-20 years of pricing stability," says Laura Spanjian, who oversaw many of Houston's green initiatives as director of the city's Office of Sustainability until late 2015.

Houston is also aggressively improving the energy efficiency of scores of city facilities, reducing their energy use by 30 percent or more, with paybacks on the investments averaging less than 10 years. Over the objections of local builders, it has required that new homes be 15 percent more efficient than required in standard building codes. It's saving $3 million a year from installing LEDs at traffic lights all its 2,450 intersections, and expects $28 million in additional savings from converting 165,000 streetlights to LEDs. It opened two new light rail lines in 2015, bringing the total rail network to 23 miles—with some of the highest ridership per mile in the nation—and stimulating a market-driven boom in new infill development. It's installed electric vehicle charging stations, a bike share system, and with private partners, added thousands of acres of green space along the city's bayous, which will also improve flood control and water quality.

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[4] City of Houston, "City Of Houston Increases Renewable Energy Purchase," available at http://www.houstontx.gov/mayor/press/20130620.html (last accessed August 2016).

[5] U.S. Environmental Protection Agency, "Green Power Procurement," 2014, available at https://www.epa.gov/sites/production/files/2015-08/documents/greenpowerprocurement508final.pdf.

[6] Morris, M. 2015. "City Council OKs 20-year solar energy contract," Houston Chronicle, November 11, available at http://www.chron.com/news/politics/houston/article/City-Council-OKs-20-year-solar-energy-contract-6623583.php. Note: This contract includes the benefit of the solar tax credits.

"It's a pretty impressive set of accomplishments," Fulton says. And especially so for a city built not just by the oil and gas industry, but also by a fierce commitment to market forces and free enterprise. "If Houston can figure it out, then everyone else ought to be able to do it," says Michael Skelly, founder and president of Clean Line Energy, a Houston-based transmission line developer.

Houston's progress towards a greener, lower carbon economy is possible because businesses and residents see bottom line improvements, Spanjian says. "It is always about saving money and using less resources," she says. "In Houston, these arguments work well." Those savings add up, especially replicated in cities around the world, according to new research from The New Climate Economy (The New Climate Economy, 2015).[7] Improving energy efficiency in buildings, investing in public transportation and taking other green steps could save cities $17 trillion in current value by 2050, the analysis shows—while also reducing annual greenhouse gas emissions by more than all of India's current emissions.

But there are larger lessons from the stories of these cities and regions. One is that there are different possible paths to a cleaner future. Much of the progress towards clean energy and lower carbon emissions in California cities is due to the state's groundbreaking mandates for renewable power and low emission vehicles, among other rules. "Regulation inspires innovation," California Governor Jerry Brown says.

In contrast, Houston, Georgetown and Texas in general are examples of an alternative approach. They illustrate the powerful force for change that comes from a felicitous combination of business talent, engineering knowhow, appetite for risk-taking, a deregulated market structure that encourages innovation, some policy incentives, and the lure of profits. "Houston has a critical mass of talent and expertise because of its history in oil and gas," Skelly says. "In addition, the rules for new generation and transmission development are set up to encourage new entrants, so there is competition and innovation."

So it's no surprise that Texas leads the nation in installed wind capacity, at more than 16,000 MW (American Wind Energy Association).[8] Another 6,000 MW is under construction and solar is growing rapidly, adding fuel to economic growth and creating jobs.

There's also growing talk among business leaders that the economic engine of Houston could sputter without such green measures as improving public transit and building parks that improve quality of life. "We talk about intellectual capital and needing to attract the best people," says Richard Kinder, co-founder and executive chairman of Kinder Morgan, the world's third largest energy company. "But we're not

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[7] The New Climate Economy. 2015. "Press release: Low-carbon cities are a US$17 trillion opportunity worldwide," September 8, available at http://newclimateeconomy.net/content/press-release-low-carbon-cities-are-us17-trillion-opportunity-worldwide.

[8] American Wind Energy Association, "Texas Wind Energy," available at http://awea.files.cms-plus.com/FileDownloads/pdfs/texas.pdf (last accessed August 2016).

going to be able to attract those people if we have a run-down city. We have to work very hard to improve our urban environment and our urban green space."

Gas and oil prices may be low today. But Houston has vivid memories of past price spikes, and the resulting boom and bust cycles. And now, business leaders say, there's an opportunity to eliminate most of that risk. "The investments we are making now in renewables are setting the stage for stable, low-cost energy for the next 30-50 years," Clean Line Energy's Skelly says.

Policy Can Work: The Story of the Regional Greenhouse Gas Initiative

In 2007 and 2008, officials in New York, Massachusetts and eight other northeastern states were working on the details of ambitious plan to cut greenhouse gas emissions in the electricity sector. The strategy was to set an overall cap on emissions and require utilities to have an "allowance" (which could be bought and sold) for each ton of carbon dioxide they emitted. The cap would be gradually lowered. As the plan evolved later, the states eventually decided to auction off most of the allowances instead of giving them away, with the money raised being used to subsidize energy efficiency improvements in businesses and homes, installations of solar panels, and other measures to create a cleaner energy economy.

But before it was finalized, the plan, dubbed the Regional Greenhouse Gas Initiative (RGGI), ran into stiff opposition. "There was a very sophisticated lobbying effort to derail it," says Peter Iwanowicz, then director of New York's Climate Change Office.

Gavin Donohue, president of the Independent Power Producers of New York, which represents companies that generate more than 80 percent of the state's power, argued that electricity prices would go through the roof, customers would be hit by blackouts, and businesses in New York would be put at a competitive disadvantage. "We were supportive of the goal of the program, but wanted to see a national program that had the endorsement of Congress," Donohue says. And while Governor Eliot Spitzer was a strong supporter, "his conservative budget people were aghast," Iwanowicz says.

In Massachusetts, the Associated Institutes of Massachusetts (AIM) warned that the plan "could have a devastating effect on all of us here in Massachusetts," said AIM's Robert Rio in early 2007 (The berkeley beacon, 2007).[9] Defense contractors, especially Raytheon, were fierce opponents.

Under attack from within and without, the plan almost died. But the supporters persevered. On September 28, 2008, RGGI made history by holding its first auction. The states sold more than 12 million allowances at a price of $3.07 per allowance, bringing in more than $38 million (Marten Law, 2008).[10]

Between then and December 2015, the RGGI states (minus New Jersey after 2011) held 29 more auctions. The total proceeds: more than $2.2 billion.

The results? Since 2005, the region's power plant carbon dioxide emissions have dropped more than 40 percent. And far from devastating the economies of the nine states, the program has brought $2.9 billion in net economic benefits, according to the

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[9] The berkeley beacon. 2007. "RGGI puts cap on emissions in Mass," January 31, available at http://www.berkeleybeacon.com/news/2007/1/31/rggi-puts-cap-on-emissions-in-mass.

[10] Marten Law. 2008. "Lessons Are Learned from First U.S. Carbon Auction," October 16, 2008, available at http://www.martenlaw.com/newsletter/20081016-first-us-carbon-auction.

most recent estimates by the Analysis Group (Hibbard, Okie, Tierney, & Darling, 2015).[11] On average, electricity bills are actually down, not up, "because these states invested a substantial amount of the RGGI auction proceeds in energy-efficiency programs that reduce overall electricity consumption, and in renewable energy programs that displace higher-priced electricity generation resources," the report says. Moreover, the program led to more than 30,000 new job-years (defined as one person working for one year). "RGGI has been a globally significant success," says Richard Cowart, a former top utility regulator and current managing director of the Regulatory Assistance Project, who served as a technical advisor during RGGI's development.

One key reason for the economic benefits is that money that used to flow out of the region to buy coal and natural gas stayed at home. "Anytime you stop sending millions, and maybe billions, of dollars out of the state to buy stuff and use that money locally, you will do well," says Sonia Hamel, leader of Massachusetts' efforts on RGGI and the state's climate action plan.

More important is how that money has been used. Instead of going to general revenues, most of it has been used to fund energy efficiency improvements for homes and businesses, to invest in renewable power, and to provide assistance to low-income consumers to pay their electricity bills. "That has doubled the efficiency spending in the RGGI states and led to very low cost carbon reductions," Cowart says. "It also has lowered the price of power, moderated demand, and led to less stress on the system."

In addition, Cowart says, "the important lesson from RGGI is that the carbon revenue [from auctioning allowances] is just as powerful a tool as the carbon price—and in some cases is a more powerful tool."

Indeed, the price per ton of carbon emissions in the RGGI states has been too low to directly spur much investment in cleaner electricity generation, analysts say (Duane , 2010; Ramseur, 2016).[12,13] But at the margin, "including a price on carbon emissions in the dispatch decisions in the region shifts output to lower- carbon-emitting sources of power," the Analysis Group report says .[14] In addition, the mere fact that a carbon price

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[11] Hibbard, P. J., A. M. Okie, et al. "The Economic Impacts of the Regional Greenhouse Gas Initiative on Nine Northeast and Mid-Atlantic States," Analysis Group, July 14, 2015, available at http://www.analysisgroup.com/uploadedfiles/content/insights/publishing/analysis_group_rggi_report_july_2015.pdf.

[12] Duane, T. P. 2010. "Greening the Grid: Implementing Climate Change Policy Through Energy Efficiency, Renewable Portfolio Standards, and Strategic Transmission System Investments," Social Science Research Network, available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1614964

[13] Ramseur, J. L. 2016. "The Regional Greenhouse Gas Initiative: Lessons Learned and Issues for Congress," Congressional Research Service, April 27, available at https://www.fas.org/sgp/crs/misc/R41836.pdf

[14] Hibbard, P. J., A. M. Okie, et al. 2015. "The Economic Impacts of the Regional Greenhouse Gas Initiative on Nine Northeast and Mid-Atlantic States," Analysis Group, July 14, available at http://www.analysisgroup.com/uploadedfiles/content/insights/publishing/analysis_group_rggi_report_july_2015.pdf

exists, along with the expectation that it will rise over time as the states ratchet down the cap as planned "gets people to include a price of carbon in their long term business decisions, which is a big benefit," Hamel says. Iwanowicz says, "It sends the right signal that carbon pollution should be reduced in the electricity sector."

Whatever the exact driver, it is clear that the northeastern states now have cleaner, cheaper power. In New York, "we're down to three percent or less of our generation from coal, and have over 6000 MW of renewables on the grid today, along with some of the most efficient power plants," Donahue says. "It shows that the private sector is willing to make those capital investments."

Even the original critics agree that RGGI has worked. "Prices have gone down, and emissions have gone down," Donahue says. "You can't deny the results of a 40 percent reduction in CO_2 emissions."

On the other hand, no one would argue that RGGI should get all the credit, or that everyone is better off now.

For one thing, critics argue, as the cap tightens and the carbon price rises, RGGI (along with cheap natural gas and tighter air pollution rules) will accelerate the trend of shutting down coal plants. The result: a major hit to school districts and local governments that depend on the tax revenues from local power plants.

For another, big electricity producers in the region believe that the program failed to live up to original promises to funnel at least some of the proceeds back to them for investments in cleaner generation, and to put caps on other sectors, such as transportation, as well.

A complication in assessing RGGI's economic impacts is that the world around it changed dramatically. The first auction in 2008 took place just as the economy went into a tailspin. And at the time, no one anticipated that hydraulic fracturing would bring a new era of cheap natural gas. Both developments caused emissions to drop—well below the original RGGI cap. In fact, AIM's Robert Rio argues that RGGI "would have been a disaster had things stayed the same. But the plunging price of natural gas completely changed the dynamic. We lucked out."

That's a minority view, one not reflected in the studies of RGGI's benefits. Still, even supporters see room for improvement. While an estimated 80 percent of the auction revenues have been used for efficiency, renewables or other energy programs, governors haven't been able to resist occasionally raiding the funds for their general budgets, as New York has done twice, for a total of $130 million. In addition, Governor Chris Christie was able to pull New Jersey out of RGGI in 2011, which other states fear is giving New Jersey's power producers a competitive advantage in the regional electricity market. "The biggest lesson is that we would be well served to put RGGI into law, rather than having participation be at the whim of the governor," Iwanowicz says. "The way the proceeds are used should be spelled out in law, so they're less ripe for grabbing for other purposes."

As U.S. Supreme Court Justice Louis Brandeis once wrote, states can serve as laboratories, trying "novel social and economic experiments without risk to the rest of the country." There's a broad consensus now that RGGI is one such experiment that has worked—and that it could be model for the whole country and other nations as well. "Climate change is too big an issue not to have a national program," Donahue says. "But why reinvent the wheel? We should use the market-based allowance trading program that's worked here."

Biofuels: Promise Dimmed by Market and Policy Trends, but Niche Markets Remain

Looming over the cornfields near Hugoton, Kansas, is a massive new facility built by Spain's Abengoa. Constructed with the help of a $132.4 million loan guarantee and a $97 million grant from the U.S. Department of Energy, the $350 million refinery was designed to make up to 25 million gallons of ethanol a year, and generate a claimed 21 MW of electricity. But unlike traditional ethanol facilities, which turn corn into fuel, the Abengoa plant planned to run on agricultural waste, mostly corn stalks.

The plant held an official grand opening in October 2014, attended by luminaries like U.S. Secretary of Energy Ernest Moniz and Kansas Governor Sam Brownback, and began to slowly ramp up production. The investment by Abengoa and U.S. taxpayers even brought a boost to the economy of Hugoton, a rural hamlet in southwestern Kansas, leading to a new motel and grocery store. Moreover, the plant was just one of three new cellulosic biofuels facilities in the U.S. POET-DSM Advanced Biofuels, LLC, a joint venture of Royal DSM and POET, LLC, opened its 20 million gallon per year plant in Emmetsburg, Iowa, in September 2014, and DuPont and Danisco held a grand opening for their plant in Nevada, Iowa, in October 2015.

But this story doesn't have a happy ending. In late 2015, Abengoa decided to seek bankruptcy (Pentland, 2015),[15] and the company shut down production at the Hugoton plant.

Such a fate wasn't what Congress had in mind in the 2000s when lawmakers laid out a bold bipartisan vision of replacing nearly one-sixth of all gasoline with "clean" biofuels made from renewable sources like corn stover in Iowa, municipal waste in California, or algae growing in plastic bags in Florida. In the Energy Policy Act of 2005 (U.S. Environmental Protection Agency, 2016)[16], Congress decreed that the U.S. must use 7.4 billion gallons of renewable fuel by 2012. The Energy Independence and Security Act of 2007 (U.S. Environmental Protection Agency, 2015)[17] then raised the ante to 36 billion gallons by 2022, of which 21 billion gallons had to be 'advanced' biofuels, such as those made from cellulose instead of corn. The government backed up those goals with tax breaks, loan guarantees, and scores of millions of dollars in grants.

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[15] Pentland, W. 2015. "Spain's Renewable Energy Powerhouse Abengoa Teeters Toward Bankruptcy," November 30,, available at http://www.forbes.com/sites/williampentland/2015/11/30/spains-renewable-energy-powerhouse-teeters-toward-bankruptcy/.

[16] U.S. Environmental Protection Agency. 2016. "Summary of the Energy Policy Act," February 8, available at http://www.epa.gov/laws-regulations/summary-energy-policy-act.

[17] U.S. Environmental Protection Agency. 2015. "Summary of the Energy Independence and Security Act," August 10, available at http://www.epa.gov/laws-regulations/summary-energy-independence-and-security-act.

Those inducements stimulated investments of more than $3 billion and spawned a new industry. Giants like BP, Shell and DuPont built demonstration plants to turn sources of cellulose, such as wheat straw and corn stalks, to fuel, while startups like Amyris and Solazyme aimed to harness yeast or algae to produce renewable fuels.

The investments, in turn, have brought enormous scientific and technical progress. Companies figured out how to use enzymes or catalytic processes to crack the tight bonds that hold the carbon atoms in cellulose together. They've been able to go beyond ethanol to fuels that can be put directly into a car's gas tank or airplane's jet engine. They've scaled up promising lab experiments into giant commercial fermentation vats —and dramatically boosted yields. With what it calls a vertical bioreactor, which resembles transparent air mattresses hung from a line, Florida-based Algenol has claimed to be able to produce more than 8,000 gallons of fuel per acre from algae, far more than the 500-900 gallons of ethanol that come from an acre of corn. "These technologies are moving forward," says James McMillan, chief engineer for the National Renewable Energy Laboratory's National Bioenergy Center. "It's possible to make almost anything."

In addition, various estimates suggest that several hundred millions of tons of biomass could be harvested sustainably nationwide each year—enough to make billions of gallons of cellulosic ethanol.

Yet despite the wave of innovation, the advanced biofuels industry has so far largely failed to become a commercially viable business. In addition to Abengoa's move toward bankruptcy, Range Fuels burned through more than $70 million in taxpayer dollars before closing down its Soperton, Georgia, factory, which aimed to convert wood into ethanol and methanol. BP walked away from a $750 million cellulosic biofuel investment, shuttering its demonstration plant in Jennings, Louisiana, a technology center in San Diego, and other facilities, saying that second generation biofuels didn't make sense financially. Exxon ended a major investment in Synthetic Genomics to make fuel from algae. Algenol slashed 25 percent of its staff and its CEO resigned in late 2015. And dozens of start-ups have gone belly up.

In addition, most of the biofuel companies that have managed to survive have done so by shifting their focus from renewable alternatives to oil to products more likely to bring profits. South San Francisco-based Solazyme, for instance, is producing lubricants, skin care products, and food. What Amyris President and CEO John Melo called "our fastest product start" is a hand cleaner for mechanics called Muck Daddy. The Emeryville, California-based company also makes drugs, cosmetics and fragrances.

Those that remain committed to advanced biofuels, such as Poet-DSM, are "struggling," as Poet-DSM President Dan Cummings remarked at a meeting in late 2015. The company has put on hold its plans to adopt the cellulosic technology at up to two dozen ethanol plants in the U.S., he said. Meanwhile, even before the bankruptcy decision, Chris Standlee, executive vice president for global affairs at Abengoa

Bioenergy, said his company had given up on new cellulosic biofuel investments in the U.S. and was looking overseas for new projects.

Why the struggles in the U.S.? Part of the problem is concern that, when full life cycle analyses are done, advanced biofuels aren't always as clean as they first seem. Yes, corn stalks or switchgrass are renewable resources—and can be turned into fuel with very low carbon emissions. But to what extent does removing crop residue from fields reduce nutrient recycling and cause soil carbon to be lost into the atmosphere? And might growing crops for fuel cause land conversions elsewhere, such as deforestation, which increase emissions? These questions have yet to be fully answered.

For the most part, however, the industry's woes are due to simple economics. "Producing fuel is the absolute bottom of the barrel," says J. Craig Venter, CEO of Synthetic Genomics. From algae, engineered yeast, or plant feed stocks, companies can produce a range of products such as pharmaceuticals, cosmetics or plastics that may be worth hundreds or many thousands of dollars per liter. "Or you can produce a liter of oil, worth maybe a buck," Venter says. "People would be pretty dumb not to shift away from fuel to higher-valued products."

In fact, the markets—and the economics—look worse today than they did a few years ago. Ironically, one reason has been the remarkable increase in the fuel efficiency of America's cars and light trucks (see transportation case study), which has cut demand for gasoline even as miles traveled has increased. "As efficiency increases and demand correspondingly falls, there is a less and less 'room' in the fuels market, and thus less and less willingness for Big Oil to yield any of this market to biofuels," says NREL's McMillan. The oil companies—and also some auto companies— have fiercely fought the idea of gasoline blends that contain more than 10 percent ethanol, citing concerns over the potential effects on engine wear and fuel systems and arguing for a limit—called the blend wall—on the amount of biofuels that the nation can use. EPA has recently allowed gasoline blends to slightly exceed the 10 percent threshold (Parker, 2015).[18]

The other big reason is the plunge in the price of oil, which dipped as low as $26.12 per barrel in Feburary 2016 (Riley, 2016),[19] which makes it harder for biofuels to compete in the marketplace.

Moreover, the biofuels industry is almost entirely the creation of government policy in the first place—and that policy commitment has waned since Congress passed the Renewable Fuel Standard mandate. Because of the limited availability of advanced biofuels and the fact that the U.S. is hitting the blend wall, the EPA has been forced to

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[18] Parker, M. 2015. "There Goes the `Blend Wall' Keeping More Ethanol Out of Gasoline," November 30,, available at http://www.bloomberg.com/news/articles/2015-12-01/there-goes-the-blend-wall-keeping-more-ethanol-out-of-gasoline.

[19] Riley, C. 2016. "Oil crash taking stocks down ... again," February 11, available at http://money.cnn.com/2016/02/11/investing/oil-price-crash/.

scale back the mandate for biofuels. Without that strong commitment—or a high price on carbon to level the playing field—the industry faces a tough future. The policy backsliding "has chilled the outlook for us, for further investing," Poet-DSM president Dan Cummings said at a recent meeting.

If the challenge isn't tough enough already, competing technologies haven't stood still. With more than 70,000 all-electric Nissan Leafs and Teslas (and tens of thousands of plug-in hybrids) already on U.S. roads along with a few hydrogen-powered fuel cell cars, biofuels run the risk of being yesterday's solution to the problem of slashing auto carbon emissions.

Still, electrification has its limitations. Batteries will never fly us from New York to Tokyo—and would also have a hard time powering the heavy trucks that keep America's commerce humming. And even if most new cars are powered by electricity, the millions of older ones still on the road will need liquid fuel.

That's why there is some continued government support for biofuels. That support can be seen in California's Low Carbon Fuel Standard, which essentially raises the price of high-carbon fuels like gasoline to subsidize low-carbon fuels like cellulosic ethanol or biodiesel. It can also be seen in the military's efforts to find low carbon alternatives for its planes and ships. In 2015, the Pentagon handed out $210 million to Fulcrum BioEnergy and two other bio jet fuel companies, Emerald Biofuels and Red Rock Bio, towards the construction of biorefineries to produce cost-competitive, drop-in military biofuels (Lane, 2014).[20] "The nation that leads the clean energy economy will lead the global economy of the future," said U.S. Deputy Secretary of Energy Dan Poneman when he made the announcements. "Winning the race to cost-competitive drop-in biofuels is a huge win for our country and for the future."

Facing the prospect of increasingly strict regulations on greenhouse gas emissions, airlines are also keeping their options open. United Airlines announced in June 2015 that it was investing $30 million in Fulcrum BioEnergy (United, 2015).[21] That move followed a previous agreement with AltAir Fuels to supply aviation fuel made from natural oils and agricultural waste to power planes flying out of United's Los Angeles hub. "Investing in alternative fuels is not only good for the environment, it's a smart move for our company as biofuels have the potential to hedge against future oil price volatility and carbon regulations," United's Executive Vice President and General Counsel Brett Hart said.

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[20] Lane, J. 2014. "US Navy, DOE, USDA award $210M for 3 biorefineries and mil-spec fuels," September 19, available at http://www.biofuelsdigest.com/bdigest/2014/09/19/breaking-news-us-navy-doe-usda-award-210m-for-3-biorefineries-and-mil-spec-fuels/.

[21] United Air Lines. 2015. "United Airlines Purchases Stake in Fulcrum BioEnergy with $30 Million Investment," June 30, available at http://newsroom.united.com/2015-06-30-United-Airlines-Purchases-Stake-in-Fulcrum-BioEnergy-with-30-Million-Investment.

The bottom line: Thanks to billions in investment and technical advances, companies already know how to make most of the renewable liquid fuels the nation would need to forge a low carbon future. And because of efficiency gains and progress in electric cars, we may not need as much as we once thought. So with a change in policy to provide more support, biofuels for some markets, especially aviation and shipping, could become a reality.

Breaking Down Barriers to Energy Efficiency

When Elias Lumpkins, Jr. and his wife, Ruth, bought their two-story house in a verdant neighborhood on the southeast side of Grand Rapids, Michigan, they put on an addition so that Ruth could have the formal dining room she always wanted. But despite that work and the perfectly manicured lawn, the brick and siding house, originally built in 1975, had its flaws. It was cold and drafty in winter, warm and humid in summer, and the utility bills were high.

So when Elias, a former teacher, principal and school administrator who now represents Grand Rapids' Third Ward on the City Commission, heard about a new program offering subsidized home energy assessments, he and Ruth decided to sign up. Home energy use normally isn't something people pay attention to—"You've got bigger fish to fry," Elias says. "But at that point in time, I was looking to see how we could lower some of those utility bills and use that money for something else."

The energy audit turned up a number of problems, from an inefficient furnace and air conditioner to mold from the dampness. So with help from a $1475 utility rebate and a low cost loan from a part of the program called MichiganSaves, the Lumpkins replaced light bulbs, had the mold removed, and new high efficiency HVAC equipment and water heater, and attic and basement insulation, installed. "It was much more than we wanted to spend, but I think it was worth it," says Elias. The Lumpkins' energy use and utility bills are down 23 percent, saving them more than $640 per year, and the drafts and high humidity are gone. "It's been phenomenal," says Ruth, a community activist and Grand Rapids Public Library Commissioner. Their total out-of-pocket cost was $15,042.53, but more than a third of that was for the mold remediation, so that they will recoup their energy efficiency investment in 12 years or less—and have the 23 percent energy savings far into the future.

Multiply the Lumpkins' story by 90 million—the number of existing single-family homes in the U.S. Then make similar improvements in another 30 million multi-family dwellings and commercial buildings. It all adds up to an enormous opportunity to cut energy use and greenhouse gas emissions in America's homes, offices, stores and other buildings.

In fact, 40 percent of all the U.S.'s energy—and 76 percent of all our electricity—is now used to keep our lights and TVs on, our appliances and equipment humming, and our temperatures comfortable. And study after study, such as McKinsey's landmark 2007 roadmap to slashing greenhouse gas emissions, has concluded that major reductions are both possible and profitable. Deutsche Bank figures, for example, that $279 billion spent on retrofitting buildings would bring $1 trillion in savings over 10

years—and create 3.3 million job-years (The Rockefeller Foundation, 2012).[22] The Department of Energy's Quadrennial Technology Review says that "by 2030, building energy use could be cut more than 20 percent using technologies known to be cost effective today and by more than 35 percent if research goals are met." (U.S. Department of Energy, 2015)[23]

Moreover, energy efficiency is often a cheaper energy source than wind or solar, since every watt saved means one less watt that must be generated.

But the existence of this huge opportunity raises a troubling question. If billions and billions of dollars of saved energy costs are lying on the table for the taking, why have we largely failed to grab that money? America has retrofitted less than 3 percent of its homes and commercial buildings. And more than two-thirds of the new HVAC systems we buy today are far less efficient than equipment already on the market, which would pay back its higher cost in savings in just a few years. In short, why are we still wasting so much energy—and money?

There are many answers. Building owners often don't know or don't much care what their monthly bills are—or have other higher priorities. Landlords have little incentive to cut energy use when tenants pay the bills. Regulators typically allow utilities to get paid only for selling more electricity, not less. And the task itself—upgrading more than 100 million buildings one by one—is enormous and daunting.

So when Michigan launched the effort that would bring energy savings to the Lumpkins and 11,000 other homeowners in the state, one key goal was learning how to surmount the many barriers. "The whole point was to not just deliver a program, but to study what works," says Jacob Corvidae, former executive director of Detroit-based EcoWorks, which participated in the effort.

The story begins in 2008 when Michigan passed its Clean, Renewable and Efficient Energy Act (Michigan Public Service Commission, n.d.).[24] The law required utilities to encourage consumers to cut energy use, and led to a small surcharge on energy bills to pay for incentives. Meanwhile, recognizing that coming up with the cash to pay for home upgrades is a challenge for most homeowners, the Michigan Public Service Commission asked a policy research firm in Grand Rapids to devise a good financing model. They proposed getting banks to provide a fund—which ended up totaling $43 million—for low cost loans by holding a modest reserve to cover defaults.

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[22] The Rockefeller Foundation. 2012. "Deutsche Bank and The Rockefeller Foundation Release Building Energy Retrofit Study," March 1, available at https://www.rockefellerfoundation.org/about-us/news-media/deutsche-bank-rockefeller-foundation/.

[23] U.S. Department of Energy. 2015. "Increasing Efficiency of Building Systems and Technologies," September, available at http://energy.gov/sites/prod/files/2015/09/f26/QTR2015-05-Buildings.pdf.

[24] Michigan Public Service Commission, "Renewable Energy," available at http://www.michigan.gov/mpsc/0,4639,7-159-16393---,00.html (last accessed August 2016).

The third piece of the puzzle was a $30 million grant from the U.S. Department of Energy's Better Buildings Neighborhood Program to launch a BetterBuildings for Michigan effort (U.S. Department of Energy, n.d.).[25] The idea: go out into dozens of neighborhoods throughout the state to figure out how to persuade people to sign up first for a $99 energy assessment, and then for the improvements the assessment identified.

It wasn't easy. "We had some theories. Some turned out well, and some failed miserably," Corvidae says.

For instance, the team thought homeowners would respond to a slick brochure and a door-to-door campaign that carefully described how energy assessors used a blower door test to find air leaks, and how simple improvements could save them big bucks. Wrong. "People had no idea what we were talking about," says Selma Tucker, director of marketing and communications for MichiganSaves. "At best, they were skeptical, and at worst hostile."

Plus, it was quickly clear that energy efficiency offered little social cachet. "Investing in efficiency has to compete with granite countertops and other traditional improvements," Tucker explains. "I've never gone to a dinner party where the hosts show off their R-49 insulation or new furnace—but they are giddy to show off their remodeled kitchen."

So the program changed its approach. Instead of talking about air leaks and lower utility bills, they focused on comfort, health and safety. Does the house have drafts? Cold floors? Rooms that were freezing without running a space heater—which could be dangerous? "That was a much better message than a blower door test," Tucker says.

But that still wasn't enough. The program burned through a lot of cash trying to go door-to-door and using direct mail to reach people in specific neighborhoods. That didn't work either. People don't want to be bothered after they get home from work, Tucker says, and "if you do mail, you are competing with the Macy's catalog and the other things people are bombarded with."

Then, the team had an "epiphany," Tucker says. Rather than trying to reach people in a geographical neighborhood, the program should target communities such as members of a church or university, or employees of a company. And it should enlist trusted leaders, such as ministers, professors or company officials, to spread the world. "The messenger really matters," says Tucker, who led the effort in the Grand Rapids area.

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[25] U.S. Department of Energy, "Michigan Sweeps Neighborhoods with Energy Upgrades," available at http://energy.gov/eere/better-buildings-neighborhood-program/michigan-sweeps-neighborhoods-energy-upgrades (last accessed August 2016).

At Grand Valley State University, for instance, Tucker offered free home energy audits to about a dozen campus leaders in exchange for pictures and testimonials that were put on postcards and sent to all faculty and staff through intercampus mail.

That worked. BetterBuildings for Michigan signed up 215 people (nearly 10 percent of all university employees) for the $99 audit, which included installing more efficient light bulbs and low-flow showerheads. Perhaps even more impressive, 60 percent made additional upgrades suggested by the audit. That's an astonishingly high rate compared to a national average of about 5-10% of people following up on the audit. In the U.S. in general, "we're still struggling to get people to move beyond the energy audit phase to do additional work—and then not just change one appliance or two, but to do the whole house insulation and upgrade," says Rachel Cluett, senior research analyst at the American Council for an Energy-Efficient Economy (ACEEE).

Another key lesson from the BetterBuildings for Michigan program is just how easy—and cheap—it is to make major reductions in energy use. In Detroit, few people could afford a $6000 retrofit, even with low cost loans and utility rebates, Corvidae says. So the program offered a pared down energy audit that focused on low cost improvements, such as sealing leaks spotted by the blower door test. "Air sealing is the fastest, cheapest way to cut energy bills in homes," Corvidae says. "We got, on average, a 15 percent energy reduction, and as much as 40 percent."

BetterBuildings for Michigan, of course, has been only one of many successful home efficiency efforts in the U.S. Standouts identified by the ACEEE include:[26]

- National Grid's EnergyWise program in Rhode Island, which does an energy audit for free, then pays for 75 percent of insulation costs up to $2,000 and up to $750 of free air sealing for homes.
- Columbus Gas of Ohio's Home Performance Solutions program, which offers a $50 energy audit and discounts on insulation and other work.
- Xcel Energy's Home Energy Squad in Minnesota, where a $70 trip to a house pays for a suite of energy-saving items, such as compact fluorescent light bulbs, programmable thermostats, and weather stripping, that are installed for free.

What all these home retrofit success stories have in common, though, is that they are driven by utilities and government programs, not solely by market forces. As a result, they depend on continued support, and can only reach a small minority of building owners. The BetterBuildings for Michigan outreach effort ended when the DOE grant ended, for instance, though the low cost loans and utility rebates are still available.

Moreover, existing market forces are often counterproductive. Contractors can make a lot more money persuading people to install new windows than to seal air leaks, for

[26] American Council for an Energy-Efficient Economy (ACEEE). 2013. "Frontiers of Energy Efficiency: Next Generation Programs Reach for High Energy Savings," January 9, available at http://aceee.org/research-report/u131.

instance, but for homeowners—and the nation as a whole—plugging those leaks is a far better deal.

So the conundrum remains. A huge opportunity to save money and energy is lying on the table. But we're only taking advantage of a tiny fraction of that chance. How can we do better?

When Georgetown University's Francis Stakey posed that question to a meeting of mayors he'd organized, "The mayors told us the best way to stimulate more energy efficiency was to hold a competition." So the university created the Georgetown University Energy Prize, which will award $5 million to one community in the U.S., selected from 50 finalists in 26 states, that comes up with the most innovative—and successful—ways to boost energy efficiency (Georgetown University Energy Prize, n.d.).[27]

Similarly, MichiganSaves' Tucker argues that the biggest challenge on the communications side is making energy efficiency sexy—which might be done by offering awards to homeowners who save the most energy. "No one will probably ever invite me to see their new insulation, but they might feel as proud of an award or plaque in their house as they do about the Cadillac Escalade parked in front," Tucker says. "That's when we can get the most amount of change."

[27] Georgetown University Energy Prize, "The Race for Efficiency," available at https://guep.org (last accessed August 2016).

Energy Storage: Indispensible to a Cleaner, More Resilient Electricity Grid

In a long career at Eveready and Pacific Northwest National Laboratory, Z. Gary Yang had a chance to explore many different battery technologies, from lithium to sodium ion. But in the late 2000s, he got particularly excited about an approach invented in Australia in the 1980s: the vanadium redox flow battery. The guts of the battery are two big tanks of dissolved vanadium, with a battery cell in between. It works because the vanadium can have different electrical charges. When a solution of vanadium with a high charge meets a low charge solution across a membrane, the result is a flow of electricity. Pumping electricity back in restores the difference in charge between the two tanks of vanadium, thus charging the battery (U.S. Department of Energy, 2012).[28]

Yang and his PNNL colleague Liyu Li realized that the vanadium flow battery has big advantages. It can be fully charged and fully discharged almost endlessly, unlike the lithium batteries that power cell phones and Tesla cars. It can be scaled up to any size by making the tanks bigger. And with nothing flammable, there's no risk of fire.

The problem, though, was that the original vanadium batteries were weak, fragile giants. They required huge tanks of vanadium to store relatively small amounts of electricity, and couldn't operate at high or low temperatures, thus requiring power-sapping heating and cooling equipment.

So Yang and Li set out to make a better battery. Tinkering with the vanadium solution, they discovered that adding hydrochloric acid solved both problems. "We doubled the energy density and were able to design a simple, reliable product without a complicated heat management system," Yang says. The approach was so compelling that Yang and Li left their safe jobs at PNNL to start a company, UniEnergy Technologies.

Now, one of UniEnergy's vanadium flow batteries sits in a parking lot in an industrial park nestled in the green hills on the outskirts of Pullman, Washington. Housed in 10 standard 20-foot shipping containers and funded with a $3.2 million grant from Washington State and $3.8 million from local utility Avista, it can supply 1 MW of electricity for up to four hours to the Avista grid or to a nearby grid equipment maker, Schweitzer Engineering. When the battery was turned on in April 2015, Washington Governor Jay Inslee said: "We're laying the groundwork for the most transformative change in the electric grid system in 60 years. When we flip the switch today, we won't

[28] U.S. Department of Energy. 2012. "Vanadium Redox Flow Batteries," October, available at http://energy.gov/sites/prod/files/VRB.pdf.

just be making clean energy. We'll be making a commitment to future generations." (Kramer, 2015)[29]

One 4 MWhour battery in Pullman won't change the world, of course. But batteries and other forms of energy storage "could have a tremendous impact on our energy future," says Heather Rosentrater, vice president for energy delivery at Avista. There is a long list of uses, roughly divided between those requiring short bursts of power and those needing hours worth of energy.

Short-term storage enables utilities to improve power quality by regulating frequency and voltage, and to integrate solar and wind into the grid by smoothing out minute-to-minute fluctuations. Because a battery can respond almost instantly instead of the few minutes it takes to ramp up a power plant, "it is just a better technology," says Richard Fiorvanti, vice president for distributed energy resources and storage at ICF International.

Those advantages have created a new and growing business—energy storage systems integration (ESSI). "ESSI players were rare three years ago, [but] today new entrants are populating the market," says a recent report from Navigant Consulting. One of the leaders is giant AES, which installed the first grid-scale battery system in 2008. The company now has 40 MW of lithium batteries, which are ideal for the short-term power applications, in Moraine, Ohio and 64 MW in Elkins, West Virginia, among many other deployments around the world (AES Energy Storage, n.d.).[30] The utilities using the batteries "are finding the systems to be so good, so accurate and so fast, they are starting to use them to replace power reserves that will run for 1-2 hours," says Matt Roberts, executive director of the Energy Storage Association. This short-term energy storage market "has been wildly successful," he says.

Adding large amounts of renewable power to the grid, however, requires longer-term energy storage. In fact, some areas in California with lots of solar power are seeing the beginning of the belly of a duck curve, where solar electricity plus base load power in the afternoon outstrips demand, causing the net load to plunge.[31] A system like UniEnergy's vanadium flow battery can soak up the excess electrons, then feed them back to the grid for up to eight hours as demand rises (the neck of the duck curve) in the late afternoon and evening as people get home from work and crank up air conditioners, do laundry and watch TV. That's why California is mandating that utilities add 1.325 GW of storage on the grid by 2020, with procurements by Southern California Edison and others running ahead of schedule. UBS Securities estimates that, globally,

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[29] Kramer, B. 2015 "Schweitzer Labs puts 'game-changing' battery power to test in Pullman," The Spokesman, April 3, available at http://www.uetechnologies.com/Schweitzer%20Labs%20Puts%20'Game-Changing'%20Battery%20Power%20to%20Test%20in%20Pullman.pdf.

[30] AES Energy Storage, "Deployments," available at http://www.aesenergystorage.com/deployments/ (last accessed August 2016).

[31] See Section A-3 for more on the duck curve.

storage capacity is already 3-4 GW, and will increase to about 6 GW by 2020 (Dumoulin-Smith, Weinstein, & Zimbardo, 2015).[32]

But the benefits don't end with regulating voltage and making renewable power possible. Judiciously placed storage can replace expensive new transmission lines and generating capacity. A 2014 study by the Brattle Group for Oncor Electric Delivery Company concluded that investing in 3,000 to 5,000 MW of distributed energy storage in Texas would save money, improve reliability and lower customers' electricity bills, for instance (The Brattle Group, 2014).[33] It can also make the overall grid—and smaller microgrids—far more resilient in the face of extreme events like Hurricane Sandy. "Energy storage is the bacon of the grid, because it makes everything better," says Katherine Hamilton, principal at 38 North Solutions.

Meanwhile, putting storage behind the meter—in homes, stores and businesses—enables customers to operate during blackouts, to lower bills by buying electricity when rates are low, and to help utilities manage demand. In the future, "we'll have a battery in every utility substation and a battery in every commercial building and lots of homes," predicts Jon Wellinghoff, former chairman of the Federal Energy Regulatory Commission.

And not just batteries. Competing technologies include storing energy by pumping water uphill or by forcing compressed air into salt caverns or tanks. They also include thousands of the Ice Bear units that a company called Ice Energy has already installed in buildings across the U.S. (Ice Energy, 2016)[34] These units are seamlessly hooked up to existing air conditioning systems to make ice at night when electricity costs are low and when air conditioners run more efficiently, and to produce cool air during the hot day. In one typical application, the Staples store in Howell, New Jersey cut daily load by 25 percent. "There will be a race for the best technologies," Wellinghoff says. "A lot will fall by the wayside."

The race is partly about cost. Innovation, manufacturing improvements and economies of scale have already sent the price of lithium batteries plunging "far faster than people can keep up with," Fiorvanti says. "Even the best minds have been wrong." Lithium battery costs have dropped from more than $1000/kWh in 2007 to under $150 today (Neil, 2016).[35] And when Tesla's gigafactory in Nevada (and perhaps Alevo's less

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[32] Dumoulin-Smith, J., M. Weinstein and P. Zimbardo. 2015. "Breaking Down the Value Proposition of US Storage," UBS, September 8, available at https://neo.ubs.com/shared/d1N9klYRsJ/.

[33] The Brattle Group. 2014. "The Value of Distributed Electricity Storage in Texas," November 2014, available at http://www.brattle.com/system/news/pdfs/000/000/749/original/The_Value_of_Distributed_Electricity_Storage_in_Texas.pdf?1415631708.

[34] Ice Energy, "About Ice Energy," 2016, available at https://www.ice-energy.com/company/.

[35] Neil, D. 2016, "In the Future, Chevy's Going to Need a Bigger Bolt," The Wall Street Journal, February 12, available at http://www.wsj.com/articles/in-the-future-chevys-going-to-need-a-bigger-bolt-1455215871.

publicized plant in North Carolina that will make a competing lithium technology (Downey, 2015)[36]) starts production, prices are expected to drop further. If the cost goes low enough, lithium could make the leap from short-term power quality applications to longer term energy storage, displacing better technologies like vanadium flow batteries, which now cost $400 to $800/kWh depending on hours of electricity provided, unless their price drops as well.

Another key question is how quickly broader markets will develop. The challenge now is that public utility commissions typically pay individual utilities or transmission companies for only one or two of the many benefits of energy storage, such as frequency regulation, says Jigar Shah, former CEO of solar provider SunEdison, now co-founder of Generate Capital. So while "energy storage is already worth more than it costs, but it is also worth way more than it pays," Roberts says. "That has held storage back."

As a result, the main drivers of the market in the U.S. have been California's mandate and change in FERC rules that allow regional transmission organizations like PJM to pay for frequency and voltage regulation technologies, like energy storage, that are faster and more accurate than ramping up a back-up gas plant. Looking ahead, however, storage is viewed as an essential part of modernized smarter grid. "Safe reliable and affordable electricity is not enough anymore," says UniEnergy's Yang. "It must also be cleaner, more resilient and flexible and cheaper. To make that transition, storage is indispensible."

[36] Downey, J. 2015. "Alevo making battery components in Concord as it nears production line completion," Charlotte Business Journal, August 19, 2015, available at http://www.bizjournals.com/charlotte/blog/energy/2015/08/alevo-making-battery-components-in-concord-as-it.html.

The Information Technology Revolution: Coming to the Electricity Grid?

For more than a decade, Stefan Grosjean worked with big box retail stores in the U.S., trying to transform them from energy hogs to energy misers. The fundamental principle behind his efforts: You can't control what you can't measure. So the first step for Grosjean's team was adding instruments that measured energy consumption every minute from lights, heating and cooling, freezers and other equipment. The next step was using that data to spot wasted energy. "Once we had the load profile, we were really surprised by what remains on at night," he says. In addition, data mining tools allowed Grosjean to compare stores to learn why some were so much more efficient than others.

With the information, "we were able to save 20-40 percent per store," he says. The success got Grosjean to thinking. One main barrier to saving huge amounts of energy in the nation's 115 million residential buildings (see efficiency case study) is lack of information. Homeowners get only a monthly bill, with no clue how much electricity is being sucked up by TVs (both on and off), toasters, dryers, air conditioners, chargers for all those devices or the old fridge in the garage. Why not figure out exactly what all the power is being used for?

When Grosjean first had the idea about seven years ago, it simply wasn't feasible. It required a meter on every appliance and software engineers to crunch the data. "I thought, okay, it's too expensive, so it's something for the future," says Grosjean. "Then the future came." Suddenly, we had the broadband internet, smart phones, cloud storage, apps, and the ability to send and update sophisticated software remotely, among other information and telecommunications technologies. All that innovation has transformed finance, banking, manufacturing and retail businesses—even transportation with services like Uber and Lyft and Tesla's regular software updates. "Why not energy too?" Grosjean asked.

He created a $249 device he calls Smappee (for "smart app for energy efficiency"), made by his Belgium-based company—also called Smappee. Using just one meter that measures power coming into a home's electrical box more than 4000 times per second, Smappee "listens" for the electrical "sound" of things turning on and running. Each appliance or device has a characteristic pattern of energy consumption, like a melody. For instance, a refrigerator has a little spike of electricity use to get the coolant flowing when it turns on. So like Shazam, the software looks for a match to the pattern in the database in the cloud, and thus is able to spot the coffeemaker, bathroom fan, refrigerator, chargers, and dozens of other devices. The detailed information is sent to your smartphone.

Smappee can't always hear the 2-watt whisper of an LED being switched on over the cacophony of a 2000-watt dryer. And the database doesn't yet include the unique patterns of all the thousands of possible appliances. But the mysteries hidden in the monthly electricity bill are now revealed. As *Fast Company* said: "Smappee lets you into

the deep, dark secrets of your electric bill. Once you know what's happening, your life —and energy use—will never be the same." (Peters, 2014)[37]

Users are finding wasted energy from freezer doors not closing properly, pumps running unnecessarily, TVs and music systems gobbling power on standby, air conditioners not properly maintained, lights left on. In addition, Smappee acts like a remote home monitoring system, since the smartphone app tells you when the garage door opens or the bedroom light turns on. "It's more than an electricity meter," Grosjean says. "It also gives peace of mind."

But perhaps the greatest value will come when devices like Smappee and its competitors go beyond measuring energy use to controlling it. If hooked up to data from the local utility, Smappee already has the smarts to turn down the air conditioner momentarily during periods of peak demand, or turn on the electric car charger when electricity is plentiful and cheap, or feed electrons from the battery in the basement or the solar panels on the roof back to the grid when there's high demand and money to be made. "Control makes the smart grid of tomorrow really possible," says Grosjean.

And it's about time. Jim Davis, CEO of Smart Wires, points out that Alexander Graham Bell would be blown away by how much phones have changed since his invention, but Thomas Edison would find today's electricity grid very familiar. "This is the last industry that has gone through any type of modernization," he says.

Thousands of companies see opportunity in that modernization. There's already a whole industry, led by companies like EnerNOC, which works with businesses, building owners and utilities to measure and cut energy use, and to reduce bills by adjusting demand. There's a growing business to install solar panels and wind turbines at or near Walmarts and other big box stores, data centers and corporate headquarters like Apple. And the hungry Silicon Valley companies who have already put a smartphone—and hundreds of new app-based services—in your pocket also want you to have a smart home and office that uses energy more efficiently. It's no coincidence, for instance, that Google snapped up wireless smart thermostat maker Nest.

Other innovative technologies are beginning to transform the electric grid itself. Smart Wires's devices on transmission lines respond to wireless commands to increase or decrease impedance on the line, allowing grid operators to instantly reroute power from overloaded lines to ones with more capacity. The software and simulation models from Integral Analytics can analyze extreme weather, along with hourly price and load data, to provide precise valuations and accurate forecasts. Or they can pinpoint exactly where new substations or new distributed generation should be sited to bring the biggest improvements in grid capacity and reliability. With the new technologies and tools, "what's possible are literally tens of billions, if not hundreds of billions, of dollars in savings across transmission and distribution," says Jon Wellinghoff, former chairman of the Federal Energy Regulatory Commission.

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[37] Peters, A. 2014. "This Monitor Shows You Exactly How Much Power Each of Your Gadgets Is Sucking from The Grid," December 10, 2014, available at http://www.fastcoexist.com/3039473/this-monitor-shows-you-exactly-how-much-power-each-of-your-gadgets-is-sucking-from-the-grid.

But there are big barriers to this transformation—the current regulatory systems and business models for most utilities. "The utilities are conflicted about this," says William Fulton, director of the Kinder Institute at Rice University. "Their revenue model for decades has been to sell more electricity and make more money. It's hard for them to get their minds around the idea of selling less electricity."

In fact, there's fear in the utility industry of a death spiral, where revenue losses from customers using electricity more efficiently or from nimble entrepreneurs selling power to the grid from competing distributed generation sources make it harder and harder for them to maintain the distribution lines needed to deliver power to their customers. "Change is coming to our industry," warns David Crane, longtime CEO of giant NRG Energy, the nation's largest competitive power generator, and an energy retailer with three million retail customers. "We can either drive the bus or be run over by the bus." And in fact, Crane himself became a casualty of the difficult transition. He was forced to resign as head of NRG in December 2015 after his efforts to boost rooftop solar and other renewables failed to impress shareholders and investors (Smith, 2015).[38]

The transition is challenging—and as public utilities, many companies are hamstrung by regulations that limit revenues to electricity sales and that only allow returns from new capital investments in generation and transmission. "The bigger utilities don't understand what's happening to them—or they do, but they can't change," Grosjean says. "They'll see Google, Smappee and others pass them, like the taxi world saw with Uber." In fact, Wellinghoff says, "the innovation is coming from third parties putting new technologies on the customer side of the meter."

That's why people in the industry are talking about two necessary changes. One is in the basic utility business model. Instead of selling electrons, utilities will be selling services. "We are moving towards utilities as platform providers," says John Di Stasio, president of Large Public Power Council (LPPC), a group of 25 of the nation's largest public utilities.

In fact, Chattanooga, Tennessee, area utility EPB has built an entirely new platform—a fiber optic communications network. With declining load growth, "we felt we needed to divest and get other revenue streams," President and COO David Wade says. The fiber optic system allows EPB to deliver both telecom and new energy services and makes the grid 60% more reliable, Wade says.

The other changes would be in the regulatory system. Following the model first pioneered in California, Public Utility Commissions could decouple electricity sales from utility profits, and grant utilities a return from investing in energy efficiency, demand response and other steps to save electricity and make the grid more efficient. Overall, "the electricity section is very capital inefficient because we haven't changed

[38] Smith, R. 2015. "NRG Energy CEO David Crane Resigns," The Wall Street Journal, December 3, available at http://www.wsj.com/articles/nrg-energy-ceo-david-crane-resigns-1449151435.

the rules of how utilities get paid," says Richard Kauffman, chairman of energy & finance for New York State. Meanwhile, opening up the grid to more competition in generation and transmission, as Texas has done, would unleash a powerful wave on innovation. "We need to make everything that can be competitive be competitive," argues Wellinghoff. "We need to let the markets do it."

Take those steps, and the results would be a grid that even Edison wouldn't recognize. "Telecom has gone through a revolution," Grosjean says. "Now it's time for the electricity market go through a revolution."

Lighter Vehicles Bring Fuel Savings—and Higher Sales

For John Tritz, an engineer at an oilfield equipment company, more drilling for oil means a more secure paycheck. But Tritz would prefer to buy *less* oil with the dollars that come out of his own pocket. That's why he traded in his Toyota Tundra pickup truck for a 2015 Ford F-150 pickup.

Thanks to a risky $2 billion-plus decision by Ford to build the F-150 body from aluminum instead of the traditional steel, the 2015 Ford truck weighs 700 pounds less than the previous year's model. By the simple laws of physics, less weight means using less gas.

So even though he bought the loaded King Ranch model with a big V-8 engine, Tritz gets 19 miles per gallon commuting to work in "brutal Houston traffic," he says. "If the Toyota got 15 mpg, I was ecstatic."

Tritz's improved fuel economy mirrors the two to four miles per gallon jump in Ford's lighter 2015 F-150 models, compared to the 2014 versions. And while a few additional miles per gallon per truck may not sound like much, "it has a huge impact," says Jay Baron, president and CEO of the non-profit Center for Automotive Research in Ann Arbor, Michigan, and leader of CAR's Coalition for Automotive Lightweighting Materials.

For one thing, a four mpg increase brings a far greater drop in gasoline use when the starting point is 15 miles per gallon, compared to, say, 40 miles per gallon, when both vehicles are driven the same distance. For annual travel of 12,000 miles a year, going from 15 mpg to 19 mpg will save 168 gallons—while going from 40 mpg to 44 mpg will save only 27 gallons per year.

Equally important, the fuel economy of pickup trucks really matters because there are so many of them. In fact, the Ford F-150 is the most popular vehicle in America, with sales of 780,354 in 2015 (Wayland & Burden, 2016).[39] Moreover, the next two top-selling vehicles are pickups. Of the 258 million registered cars and light trucks in the U.S., about 18 percent are pickup trucks. That means there are more than 46 million on U.S. roads hauling supplies, pulling trailers, getting the groceries or bringing the kids to school.

So do the math. If every pickup truck went from 15 to 19 miles per gallon, that 168 gallons saved each year adds up to an annual savings of 7.7 billion gallons of gas saved a year. At $2.50 per gallon of gasoline, that would leave an extra $19 billion dollars in the pockets of owners like Tritz. "Heck yes, it saves me money," he says. That's money he can spend on fishing gear or eating out, pumping the dollars back into the local economy. Plus, his new dark gray-green F-150 handles better than his previous trucks and does a better job hauling his boat to his lake house.

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[39] Wayland, M., and M. Burden. 2016. "Auto industry sets all-time sales record in 2015," The Detroit News, January 5, available at http://www.detroitnews.com/story/business/autos/2016/01/05/auto-sales/78295542/.

And still more gains are possible. Because pickup truck buyers typically care more about brawn than fuel economy, Ford actually hedged its bets, using some of the weight savings to boost the towing and hauling capacity for each new model, compared to the 2014 versions. If regulators or the market demand dictate further efficiency improvements, "Ford could convert that extra towing capacity back to fuel economy," Baron says. Higher mileage is expected anyway when Ford introduces a planned, more efficient 10-speed transmission.

The Ford F-150 redesign shows how companies can seize business opportunities on the path to the clean energy economy, taking risks now to avoid bigger risks later. It illustrates the relentless pace of innovation in materials and manufacturing that has brought—and continues to bring—gains to smartphones, wind turbines and countless other products and services. It shows the crucial role of regulations and policy. And it's just one of the myriad possible steps, from public transit and changes in urban land use patterns to cars powered by biofuels or electricity, which can bring major reductions in the amount of fossil fuel that Americans burn to get around.

Before he took over as CEO of Ford in 2006, Alan Mulally was intimately familiar with the efficiency gains that come from lighter weight. At Boeing, he had pushed a risky (and ultimately very successful) move to build Boeing's new airplane, the 787, from carbon composites instead of heavier aluminum. When he arrived at Ford, he wondered why cars are so heavy, insiders recall. By 2009, he decided to put Ford's top cash cow, the F-150 pickup, on a diet.

"Our objective was to find materials that allowed us to design the truck to be as tough —or tougher—than the current model, yet could help it be hundreds of pounds lighter for better capability and fuel economy," says Peter Friedman, manager of the manufacturing research department at Ford Research and Advanced Engineering.

The key material: aluminum. To use it for the truck body, though, "Ford had to change their entire manufacturing process," says David Cole, chairman emeritus of the Center for Automotive Research. The standard joining method—spot welding—wasn't possible, for both technical and intellectual property reasons. So Ford developed methods for joining parts with adhesives and rivets. That actually brought further weight gains, since bonded panels are stronger than those attached with spot welds, requiring less metal overall. Ford also depended on advances in design and simulation software to design tooling capable of stamping panels from aluminum, which is more finicky than steel.

Making the switch was "a very calculated and informed risk," says Ford CEO Mark Fields. Experts say Ford may have been the only one of Detroit's Big Three automakers capable of pulling it off, because of its previous experience with aluminum as owner of Jaguar.

Now, the gamble appears to be paying off. Despite production glitches and higher manufacturing costs, the F-150 remained the top-selling vehicle in the U.S. in 2015, and sales rose 7% in the first four months of 2016—to 256,895—over the same period in 2015. "I think Ford has done a fabulous job with this," Cole says. "It was a very bold move and one of the most impressive steps I have seen in a long time."

But innovation isn't stopping there. By using scanning electron microscopes to understand the nanostructure of metal and by tinkering with the amounts of alloying agents like zinc and magnesium, Ford supplier Novelis has developed aluminum that's two to three times stronger than the 6000 series metal in the F-150 body. Meanwhile, steelmakers are responding to the competitive threat by developing their own higher-strength, lighter weight materials—up to 100 times stronger than just a few decades ago. In fact, one lesser-known part of the F-150 story is a steel frame that's 60 pounds lighter than in the previous model, thanks to better steel.

The materials race is also getting a new challenger, carbon fiber composites. Growing experience with carbon fiber in airplanes, bicycles, golf clubs and a few high-end cars has brought the price down from more than $30 a pound to less than $8 over the past decade, and shortened the time for making parts from more than half an hour to a minute or two. That's enabled BMW to offset the extra weight of the batteries in its electric i3 model with a lightweight carbon fiber structure, and to make extensive use of both composites and aluminum in its latest 7-Series models. Add in countless other improvements in engines, tires, drive trains and other parts, and "right now there is a full-court press on every automobile technology that offers better fuel economy," Cole says.

What's more, each lighter, more efficient component contributes to a virtuous cycle. A lighter body makes it possible to use a smaller, lighter engine (or a smaller, lighter battery pack in an electric car) to get the same performance, for example, which reduces overall vehicle weight even further.

The larger lesson from the Ford F-150 and other vehicles is that, as with other chapters in the clean energy economy story, we already have the technology to make significant—even dramatic—reductions in fossil fuel use. Moreover, innovation wizardry and the journey down the learning curve continue to bring better and cheaper solutions, making it possible to envision a cost-effective transition to all-electric cars.

But what is driving the transformation now and in the future? With gasoline prices low, right now, the main answer is regulation. Ford's expensive and risky investment gives the company a big competitive advantage in the race to meet higher corporate fuel economy standards—which now are scheduled to rise to an average level of 54.5 miles per gallon for the 2025 model year. Water down those standards, however, and the drive to higher vehicle efficiency could lurch to a halt unless a jump in oil prices—or other policy tools, such as a price on carbon—offer new market incentives for efficiency improvements.