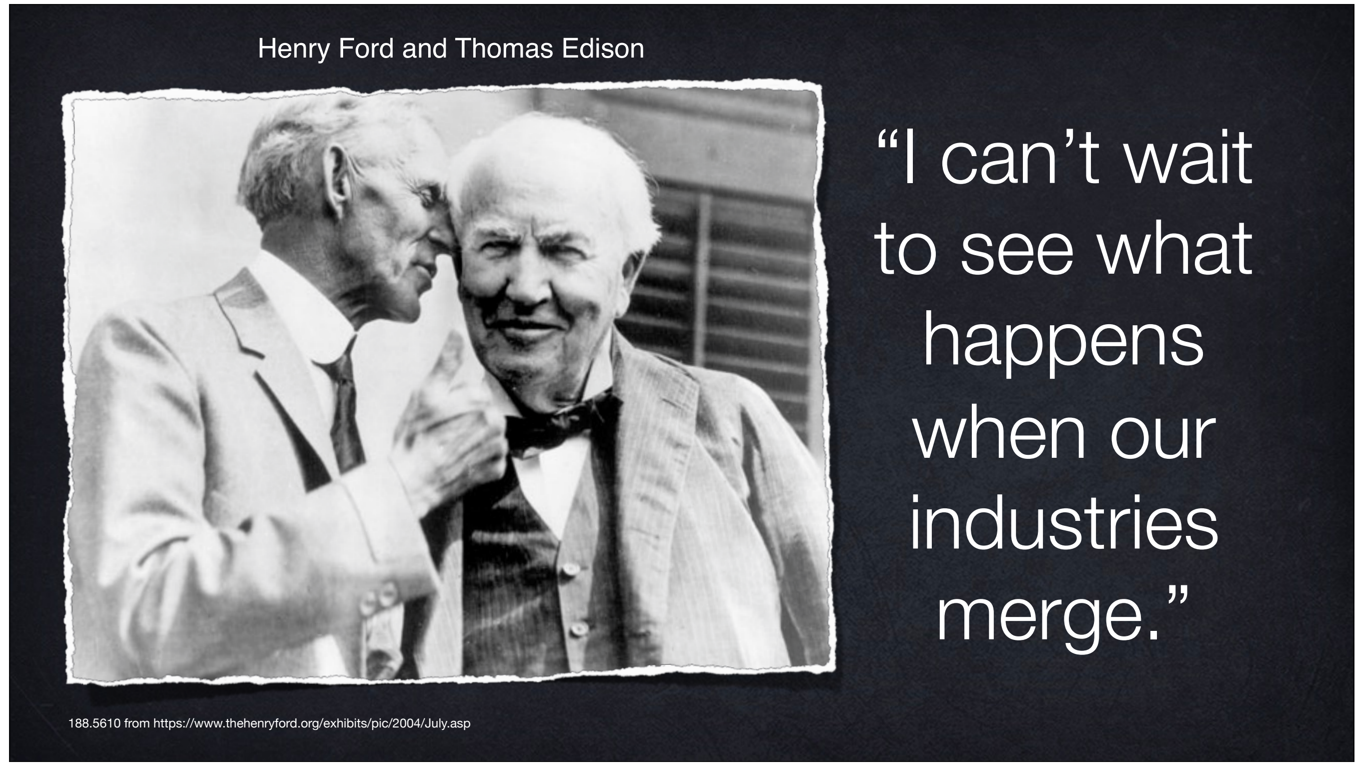
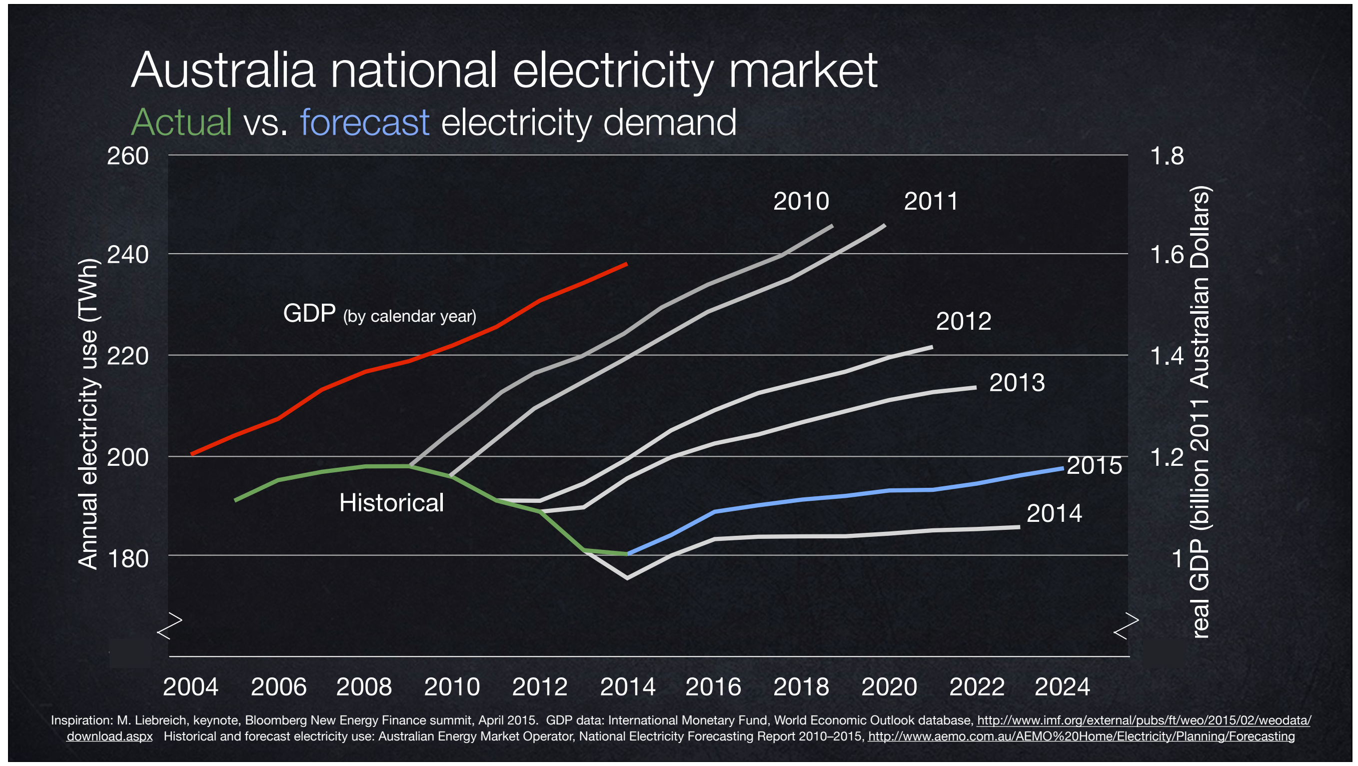
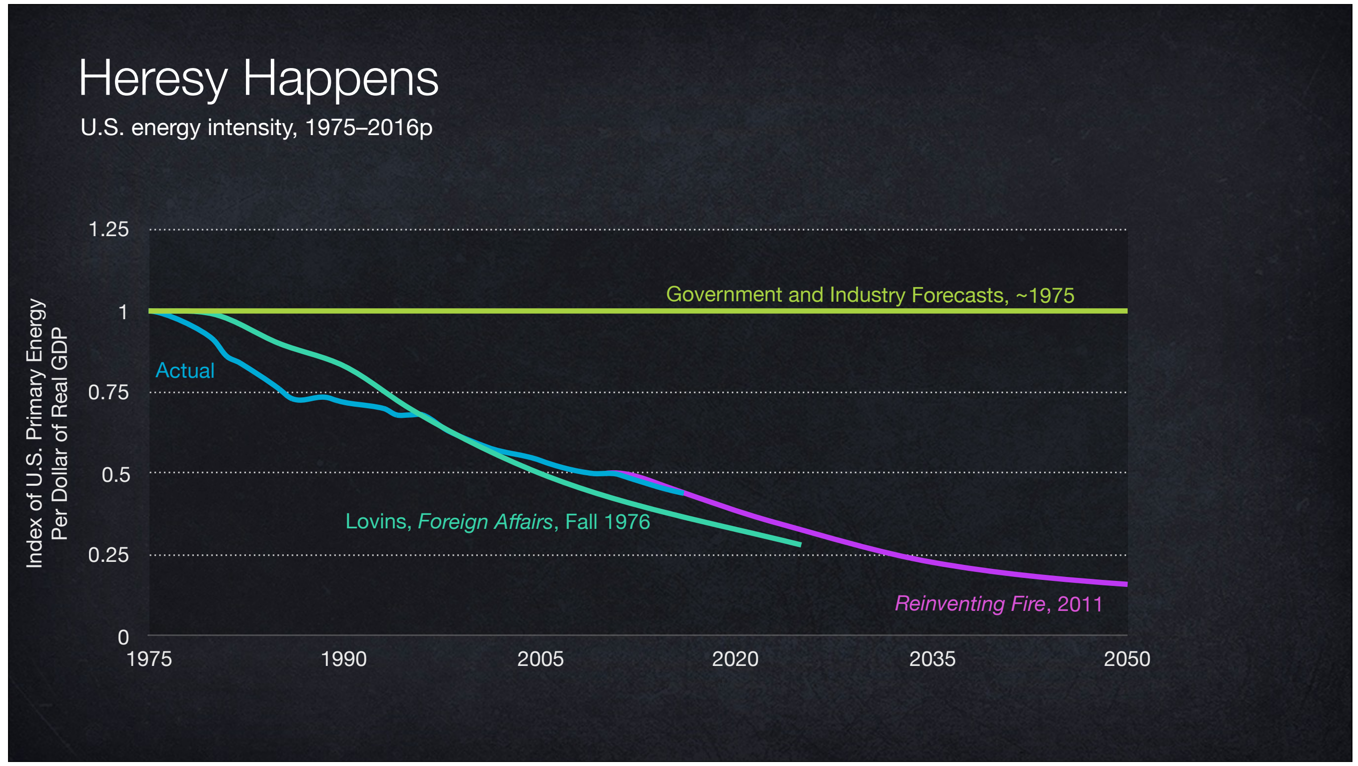
Thank you for the honor of adding some context and connective tissue to the energy transformation we're all creating together. *



Edison’s electricity industry, Ford’s auto industry, and Rockefeller’s oil industry changed the world. If Ford and Edison took a very long nap on one of their car-camping trips, woke up, and saw their businesses today, they’d recognize almost everything except the electronics. Yet today their industries face vast disruptions, as 21st-Century technology and speed collide head-on with 20th- and even 19th-Century institutions, rules, and cultures. Let me sketch how the first two of these great industries are coming together to eat the third.
As we might imagine * Ford mischievously muttering to Edison, let’s see what happens when electricity displaces gasoline, then those electric cars add flexibility and distributed storage that help the grid accept variable solar and windpower, and electric cars make batteries cheap for distributed solar—all replacing giant power stations and the fossil fuels they burn as society more quickly *saves electricity* and *makes it differently*. *



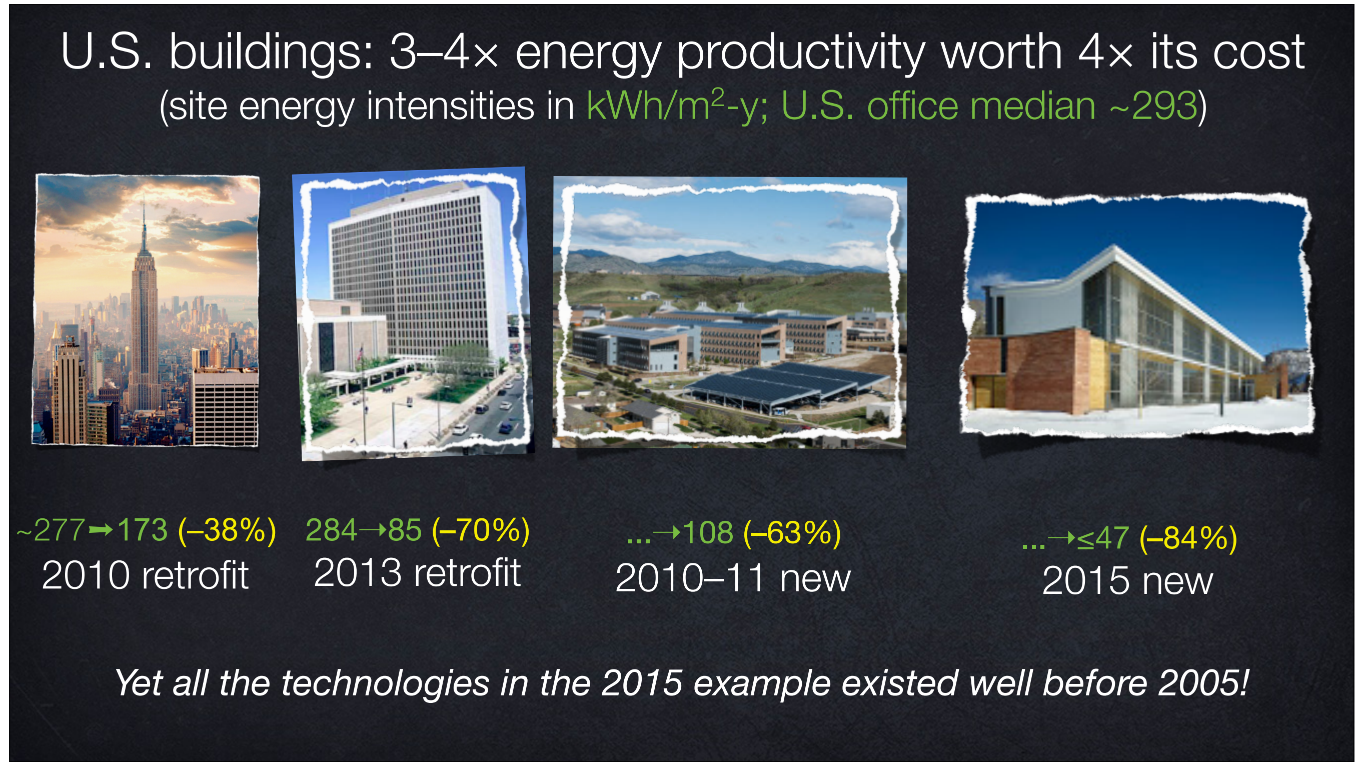
Australia just saw a decade of economic growth while electricity demand turned down, cutting by about a fifth the utilities' projected 2020 revenues. U.S. electricity demand has trended downward for a decade. Many developing countries too are seeing demand growth slump or even reverse. *



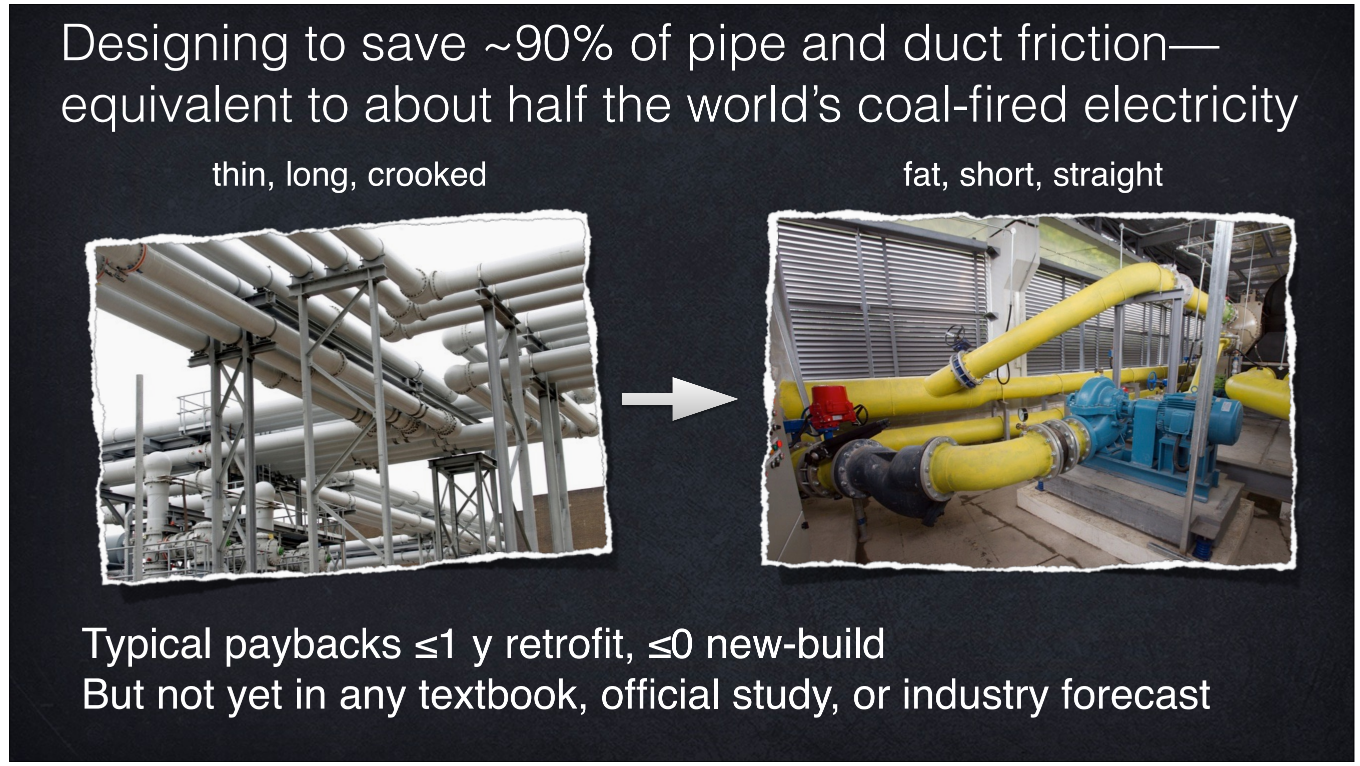
So let's start with energy savings—the world's biggest source of energy services, bigger than oil, and in the U.S., already saving over 30x as much cumulative energy as doubled renewables added. But improved technical efficiency in using energy—about two-thirds of U.S. savings so far—is just getting started. In 1975, U.S. government and industry all insisted the * energy needed to make a dollar of GDP couldn't fall. * A year later, I heretically suggested energy intensity could drop 72% in 50 years. * So far it's dropped 56% in 41 years. Yet just the innovations already made by 2010 * can save *another* threefold, twice what I originally thought, at a third the real cost, and seven years later, that looks conservative.

That's partly because optimizing vehicles, buildings, and factories as whole systems can often make very big energy savings cost *less* than small or no savings, turning diminishing returns into *expanding* returns.*

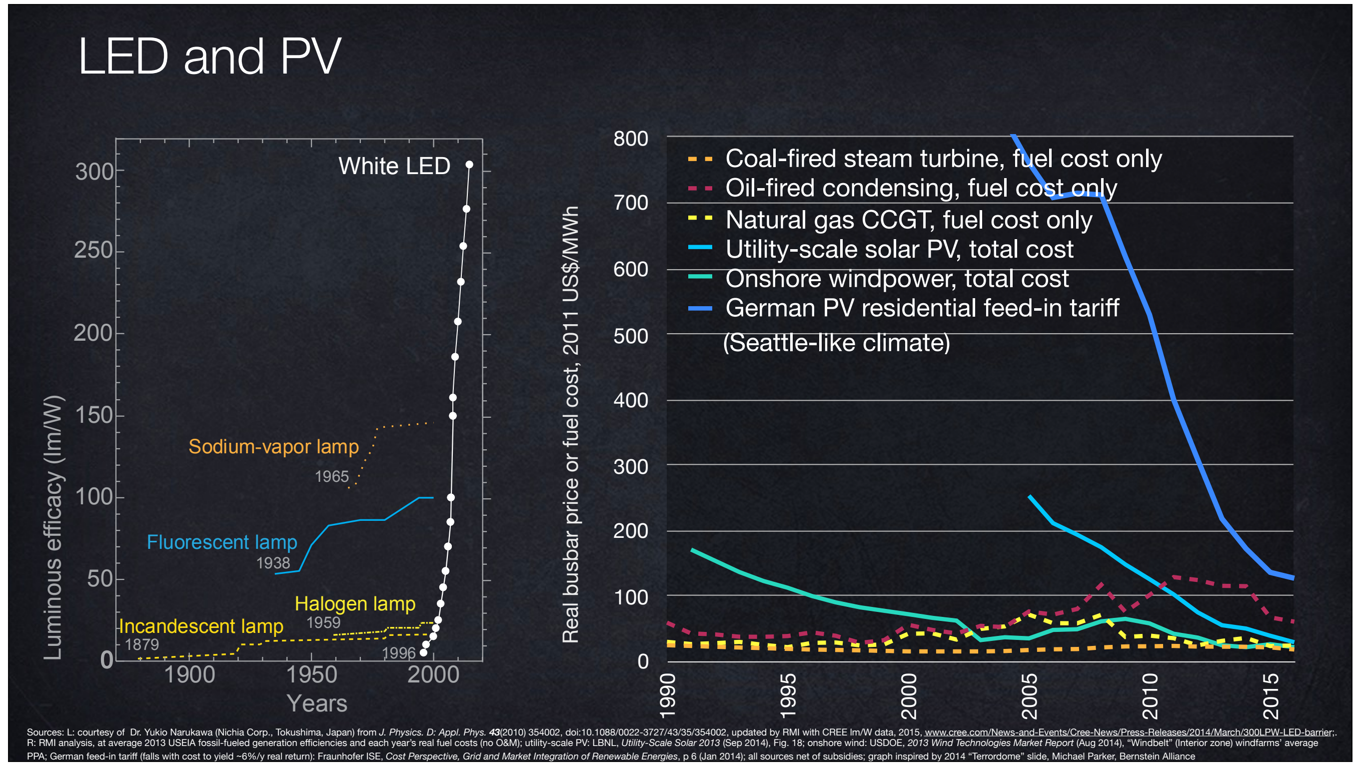
* For example, my wife and I live at 7100’ near Aspen, where temperatures used to dip as low as –47˚F. But our house does no combustion (that’s so 20th-Century). Superinsulation, ventilation heat recovery, and superwindows that insulate like 16–22 sheets of glass (but look like 2 and cost less than 3) make it 99% passive-solar heated, 1% active-solar. Eliminating the heating system *more than paid up front for the efficiency that displaced it*, and saving ~90% of household electricity too still paid back in 10 months.
The central * atrium, seen here in a February snowstorm, has produced * 69 passive-solar banana crops. Without needing to look like this, our house helped inspire over 40,000 European passive buildings that likewise have no heating and roughly normal construction cost. * This works from Old Snowmass to Bangkok—a climate range that includes nearly everyone on earth—but wherever you live, integrative design gives many benefits from each expenditure: this white arch *[point]* has 12 functions but only one cost. *



Such "integrative design" is how our * Empire State Building retrofit saved 38% of its energy with a 3-year payback. But three years later, our * cost-effective retrofit of Denver's Byron Rogers Federal Center saved *70%*, making this half-century-old office more efficient than the * best *new* U.S. office (at NREL in Golden)—which in turn is * less than half as efficient as our own new net-positive, no-mechanicals office in Basalt. Yet its technologies existed over a decade ago; what * mainly improved is not technology but *design*, the way we choose and combine technologies to obtain many benefits from each expenditure. *



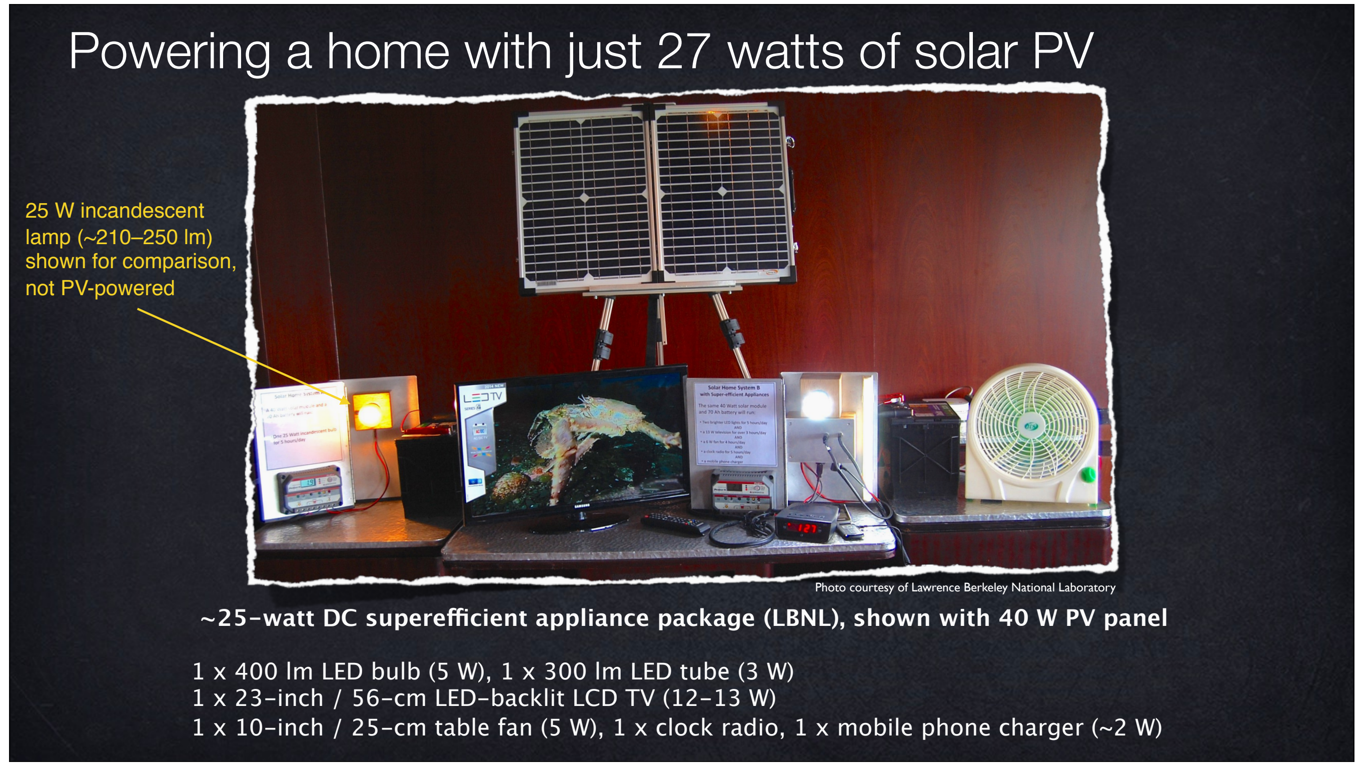
Another example: proper pipe and duct design could save roughly half the world’s coal-fired electricity with extremely juicy returns. Such rearrangement of our mental furniture as designers remains largely unnoticed because it’s not a technology; it’s a design method, forgotten since the Victorian era. *



Both technology and design are moving efficiency into fast-forward. * Prior lighting * improvements are being * swept away as LEDs each decade get 30x more efficient, 20x brighter, and 10x cheaper. Saving an eighth of the world's electricity, they're stressing electric utilities, which since 1892 have sold electricity as a commodity, not the services customers want like hot showers and cold beer, so efficient use doesn't cut utilities' *costs*; it cuts their *revenues*. [Oil and gas companies make the same mistake.] /

What else changes this fast? LEDs backwards are * PVs (photovoltaics), now less capital-intensive than Arctic oil. In the past five years, their plummeting prices have made solar and windpower cost less than US power plants' fossil fuels (the dashed lines), often making old coal, gas, and nuclear plants shut down as uneconomic to run. *

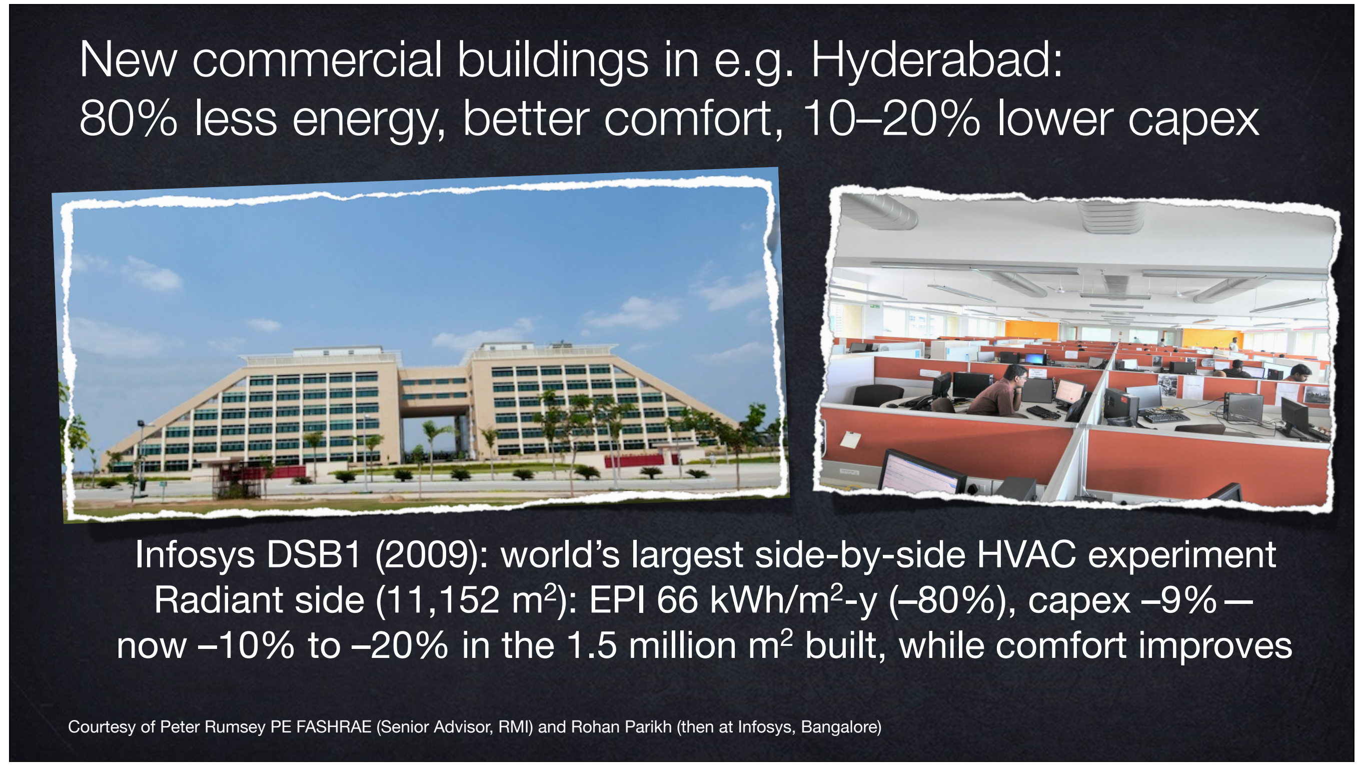
Now combine LEDs with PVs to serve the billion-plus people with no electricity, but little prospect of getting or affording it from the faraway and costly grid. Their kerosene lamps kill 4 million people a year and would rank eighth among nations in carbon emissions. The kerosene costs $38 billion a year, one-fifth of global lighting's total cost—to deliver, very inefficiently, just one-*thousandth* of the world's light. But together, very efficient LEDs, PVs, batteries, and chip controls can banish darkness so daughters and sons can learn to read. An entrepreneurial village woman can sell or lease an * integrated high-performance lighting package, like this *[demonstrate WakaWaka]*, that shines for 10–150 hours on one day's sunlight, pays back in weeks to months against kerosene, and can be microfinanced by scratch-cards or via the smartphone it recharges. Eliminating kerosene gives that $2-a-day household a month's extra income each year in perpetuity. *



Berkeley Lab uses PVs one-third smaller than shown to power 7,000 lux of LEDs, a mobile-phone charger, a clock-radio, a table fan, and a 56-cm color TV. Their high efficiencies cut total capital cost by half, empowering twice as many off-grid families for the same money, and enabling cheap and highly reliable DC solar microgrids. *

To give the girls in those families more time to study, smarter pots could be at least as important as better cookstoves and perhaps culturally easier, but they're scarcely on the agenda. Many of these proven improvements could be adapted by ingenious local metalsmiths to local skills and needs, designed cleanably and durably, and integrated with the stoves. Integrating *all* options [—including good old ideas like lower heated mass, better insulation [including haybox], direct immersion or contact, and fast regulation—] may cut cooking energy by around 10x, perhaps nearer 100x, before using solar power or heat. *

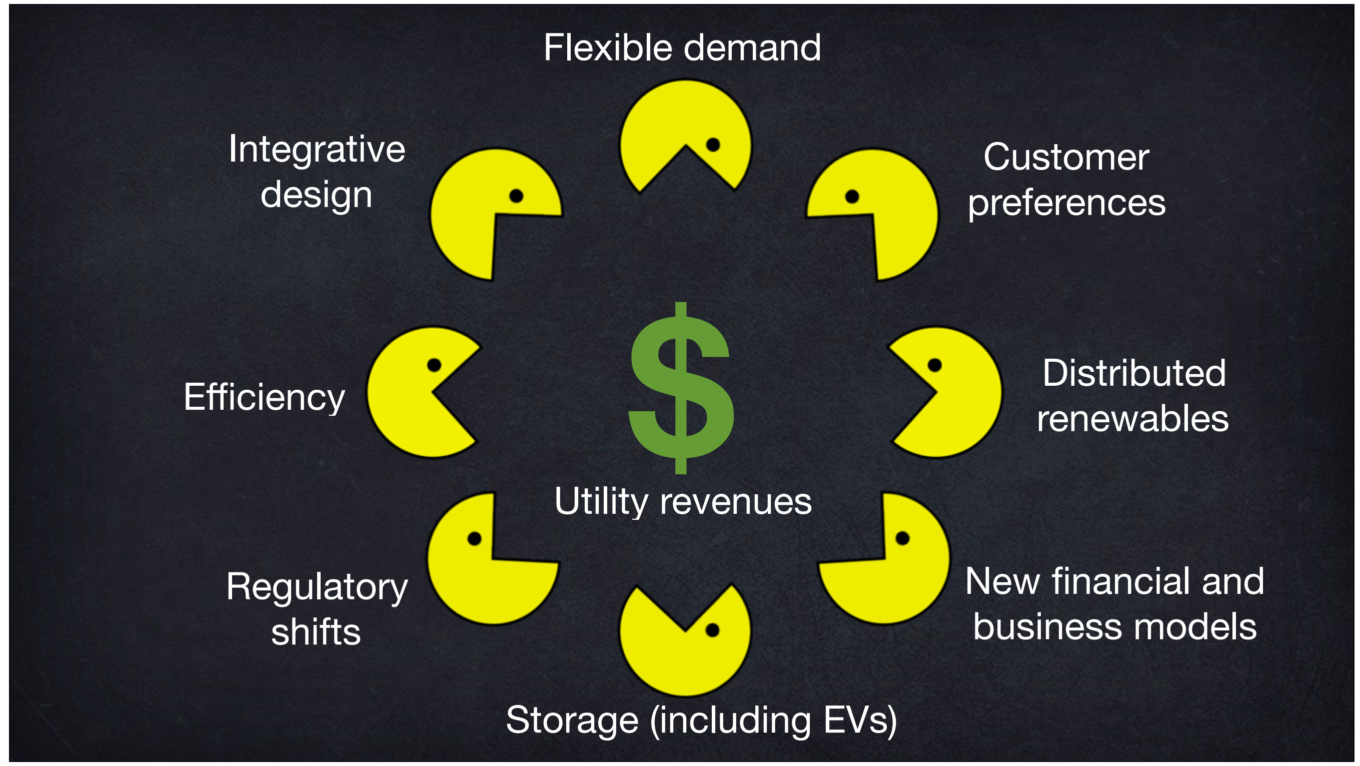
Volcano kettle: ttp://www.happypreppers.com/sitebuilder/images/Kelly-kettle-12-450x354.jpg, http://www.happypreppers.com/sitebuilder/images/Kelly-kettle-12-450x354.jpg
Simplex kettle: https://cdn.shopify.com/s/files/1/0233/7949/products/copper-kettle-stove-close-up-landscape_mg_13841_360x360_large.jpg?v=1373523381
BelKraft condensate-recycling lid: http://alintelhouse.com/yahoo_site_admin/assets/images/7ply.101105606_std.jpg, http://alintelhouse.com/yahoo_site_admin/assets/images/7ply.101105606_std.jpg
Kuhn double-walled and -lidded pot: https://ch.kuhnrikon.com/out/pictures/master/product/6/d95328c073792617327351addcbc704b_durotherm_ip4.jpg
Belkraft Vacumatic: http://www.belkraftcookware.com/why-choose-our-products/belkraft-vs-store-bought/
Thermal Cookware: https://www.thermalcookware.com/main.php?mod=Dynamic&id=22



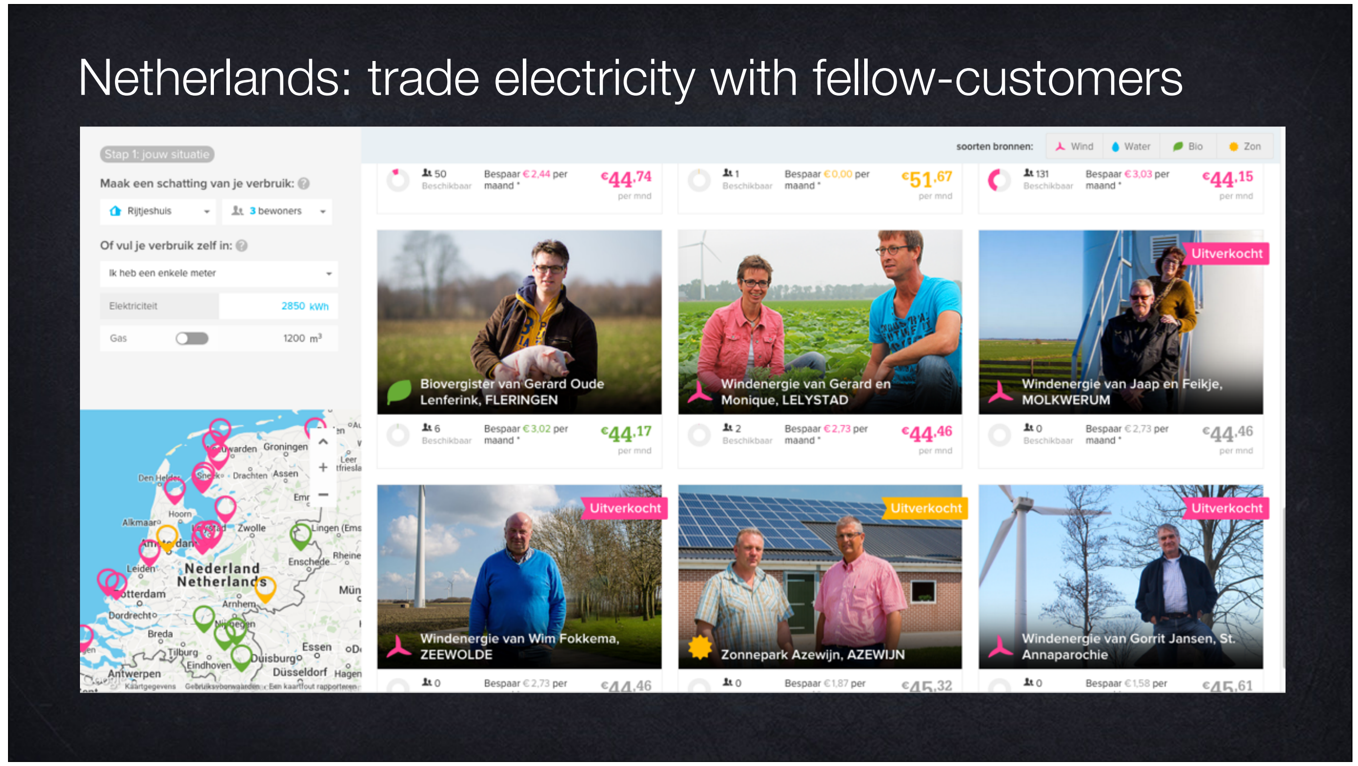
Or in India's muggy cities, Rohan Parikh's team at Infosys built every quarter a ~22k-m office using 80% less energy than the Indian norm, with 10–20% lower capital cost, 60% less cooling capacity, yet superior comfort and satisfaction. Glarefree daylighting is delivered throughout by contract: if workers complain they want blinds, the architect doesn't get paid.

Add up savings like these, plus others uncounted in old and new industries, and India appears to have on the order of 1,000 GW of profitable efficiency potential not in current forecasts. If efficiency gained the same focus and ambition that made renewables beat coal in the past few years, India's vast solar potential and 2–3 TW of cost-effective windpower could probably make it an energy-surplus country now disguised as an energy-deficit country, and could strand the ~50 GW of coal plants in the pipeline.

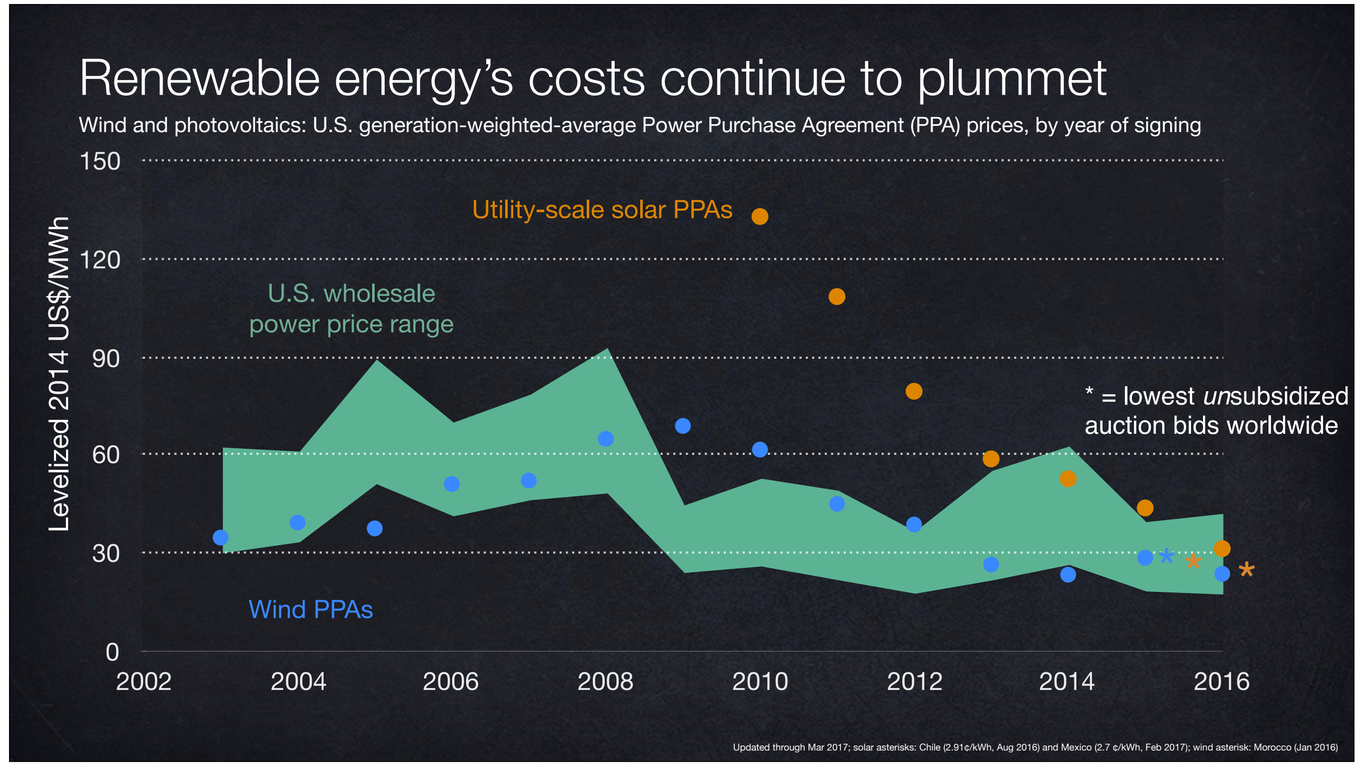
But competition from efficiency and renewables is just the start of fundamental disruptions emerging in *every* country, as we now see starkly in the EU and US. *



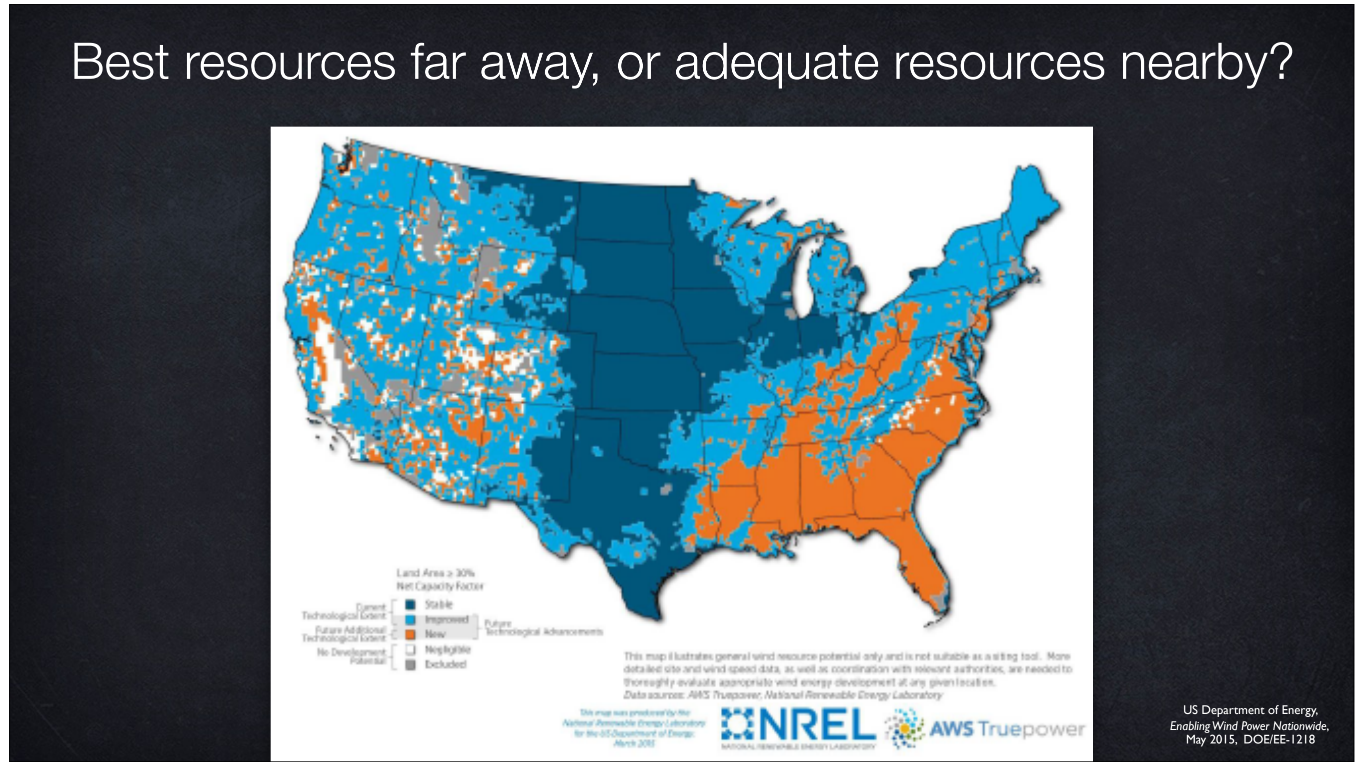
Powerful * disruptors are * converging on * utility revenues from at * least *eight* directions.
These “eight PACmen of the apocalypse” move fast. They don’t just add; they exponentiate. They’re not lone wolves; they hunt in packs, they multiply quickly, and they can gobble half of US utility revenues in the 2020s. Together they’re creating an alien competitive landscape, faster than most utility cultures can cope. Nearly three years ago, all central power plants were called “dinosaurs”— “too big, too inflexible, not even relevant for backup power in the long run.” Who said that? Not Greenpeace but Union Bank of Switzerland. /
It’s usually a good idea to sell customers what they want before someone else does, and customers are figuring out that they can use less electricity more productively and timely, produce their own, and even trade it with each other. *



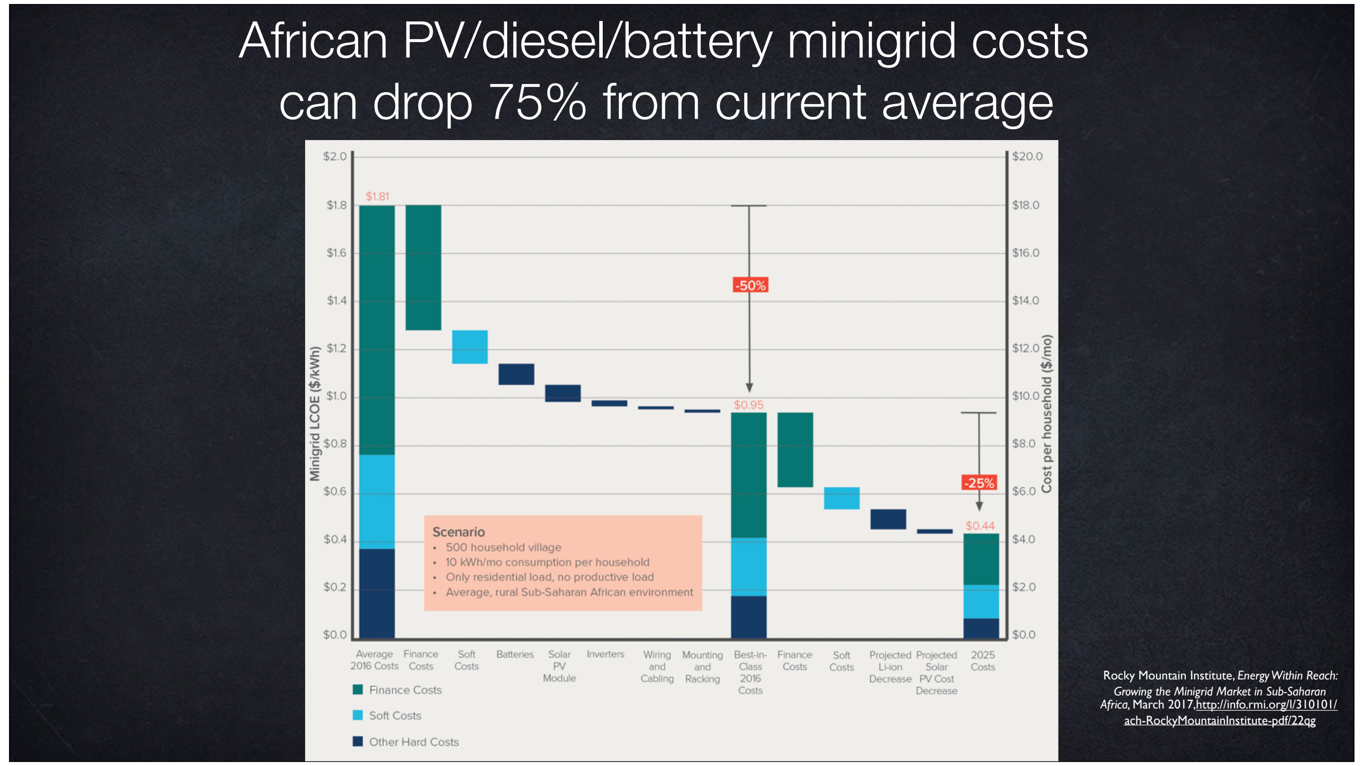
For example, Dutch customers can buy renewable electricity directly *from other customers* on this peer-to-peer website of Vandebron, literally “from the source”. A utility executive I know bought his electricity from the guy in the upper left because the price was right and he liked the cute piglet—then he got a long handwritten Christmas card from his electricity supplier. What big utility can dream of such customer intimacy? Oink! *



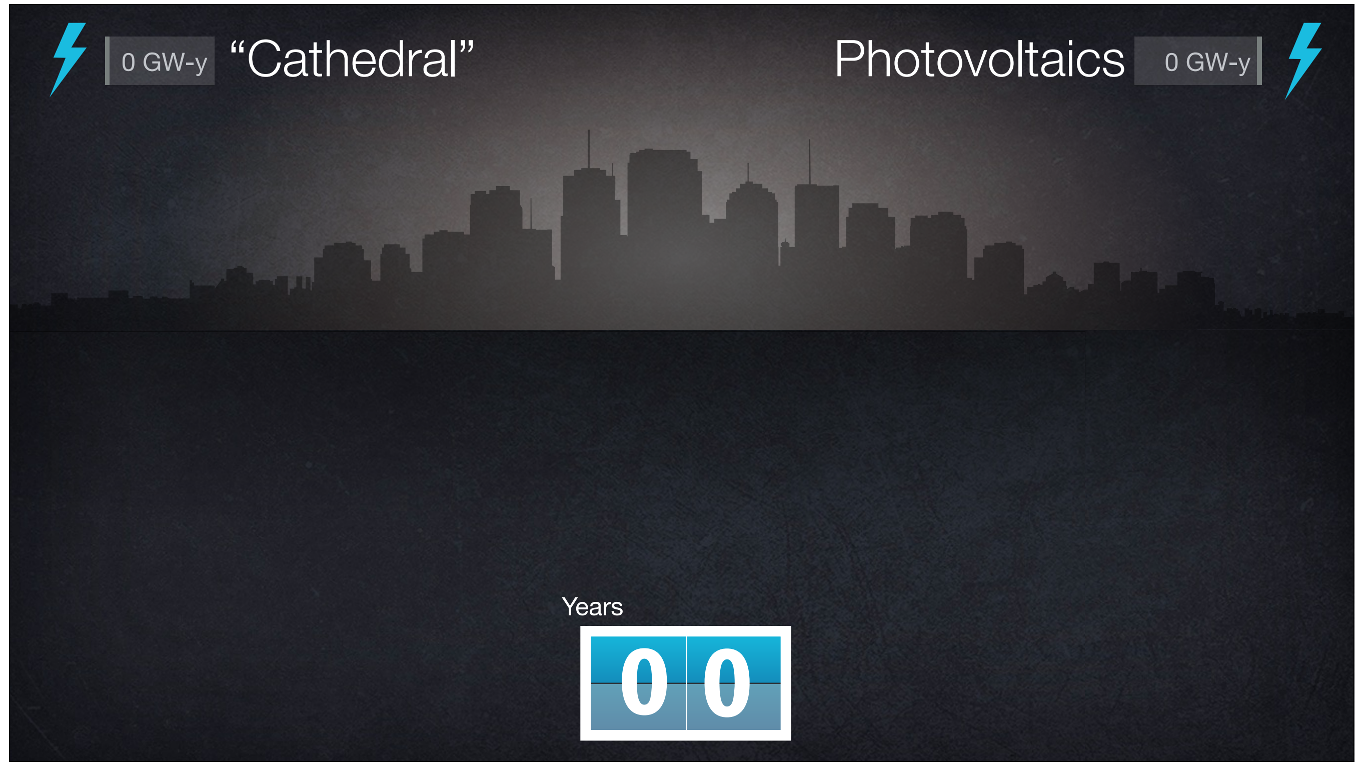
* U.S. wholesale * electricity prices are now widely undercut by the average long-term fixed prices of * windpower and * solar power. Even without their temporary subsidies—generally smaller than permanent subsidies to nonrenewables— * *un*subsidized wind and solar at or below 3¢/kWh, graphed here as asterisks, are now winning in global markets. Renewable analyses done last year or even this past spring are already obsolete: during 2016 alone, the low bids for Mexican PVs fell by 37% and for European offshore wind by 43%. *



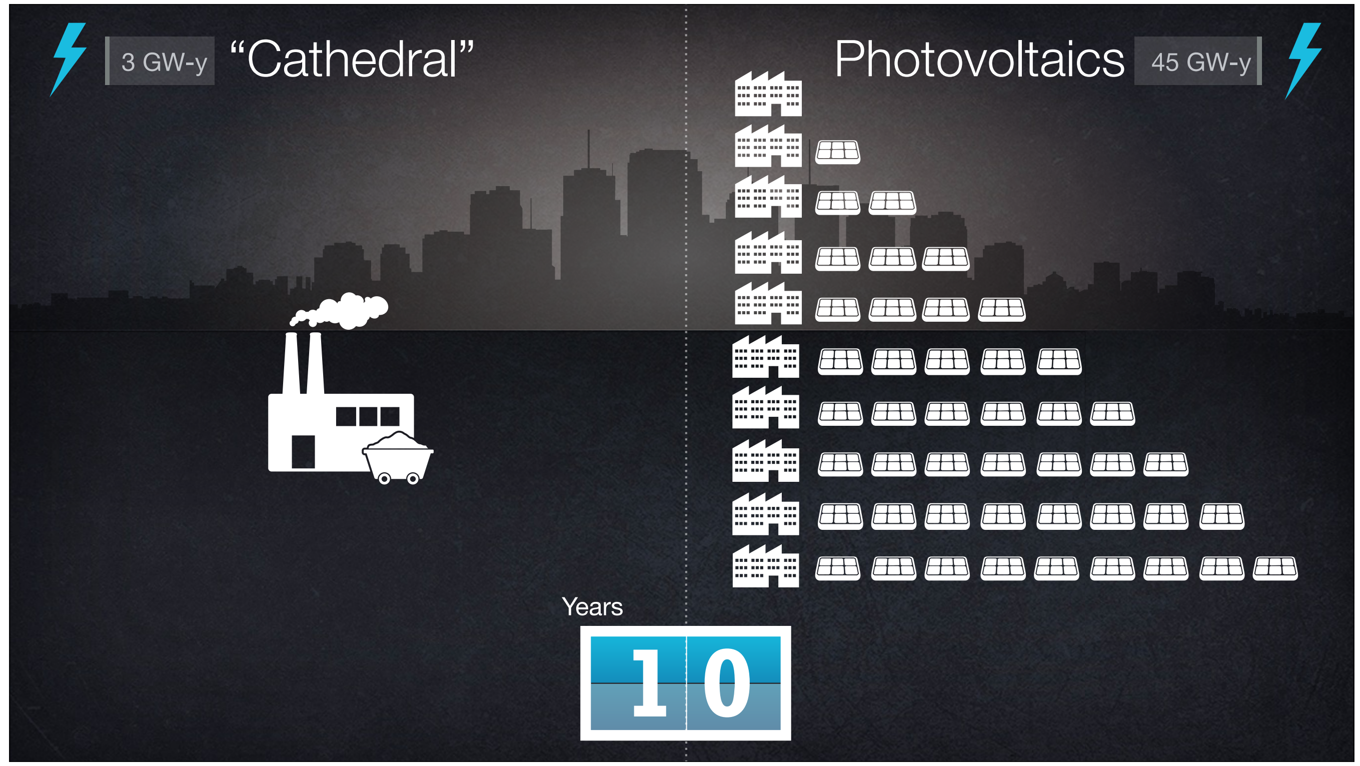
And renewable costs keep falling. Just in the seven years to 2015, taller towers and better [higher-solidity] rotors made U.S. windpower resources two-thirds bigger, spreading competitiveness from the dark blue to the light blue to the orange areas, to every state in the U.S.—and also in Germany, obviating one if not both of its big transmission corridors because best renewables far away often can't beat lesser ones nearby. My colleagues' analogous whole-system innovations for PVs can greatly increase their addressable market by getting *1*-MW distribution-connected groundmount arrays down to ~2.5–3.5¢/kWh unsubsidized. *



Similarly, RMI's new analysis *Energy Within Reach*, informed by our Rwandan fieldwork, found that though the best African minigrids cost half as much as the average, they also cost twice what they should and could if techniques we've proven elsewhere were systematically applied. A concerted effort by private, public, and development sectors can unlock this potential—perhaps quickly, because… *



[animation plays for 17s] *Modern renewables scale up in a fundamentally different way*. Traditionally, we built giant cathedral-like power plants, each costing billions of dollars and taking many years to license and build. But now *each* year, with roughly comparable capital, you can build a factory that produces *each year thereafter* enough solar cells to generate *each year thereafter* as much electricity as your “cathedral” ultimately will. So solar output worldwide is scaling faster than cellphones. In 2013, China added more PV capacity than the US had done cumulatively in the previous 59 years. In 2016, China added twice that much—three soccer fields per hour—including 11 GW in June alone. *



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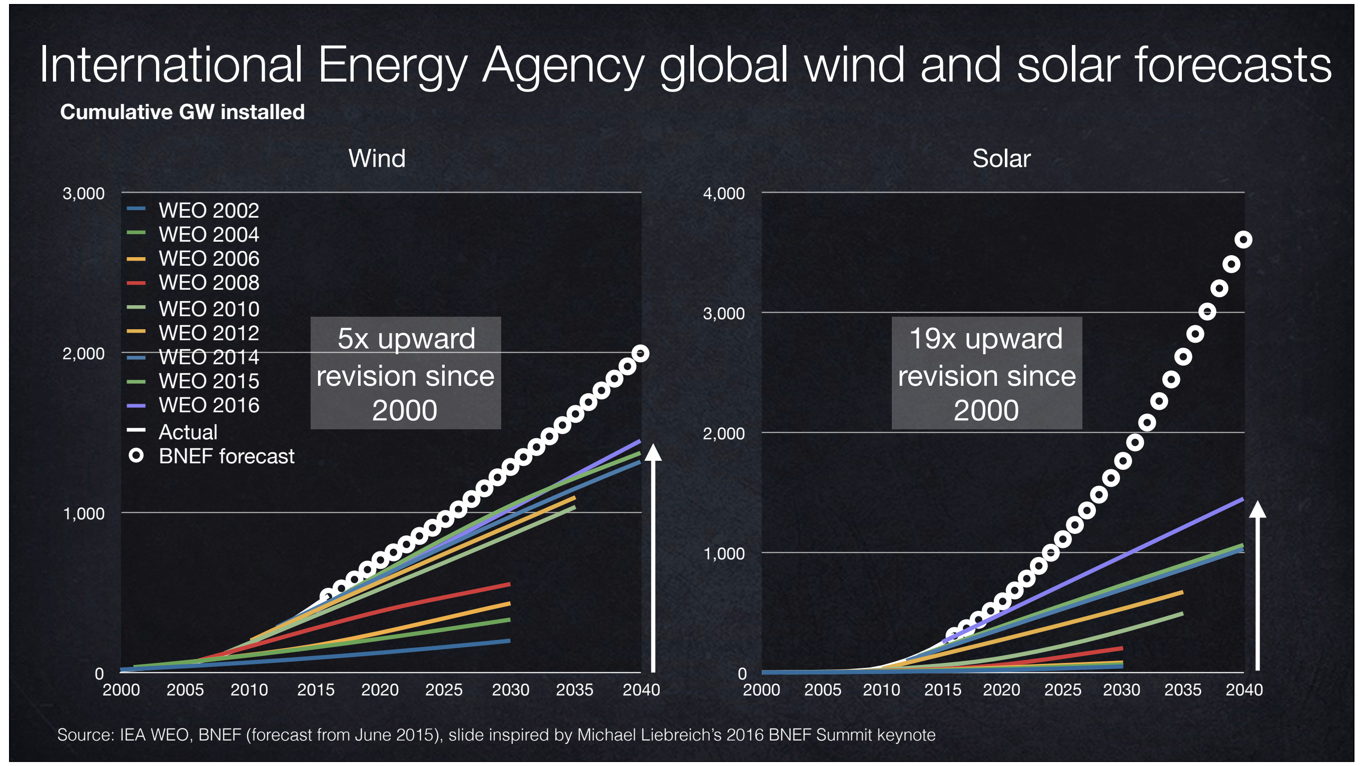
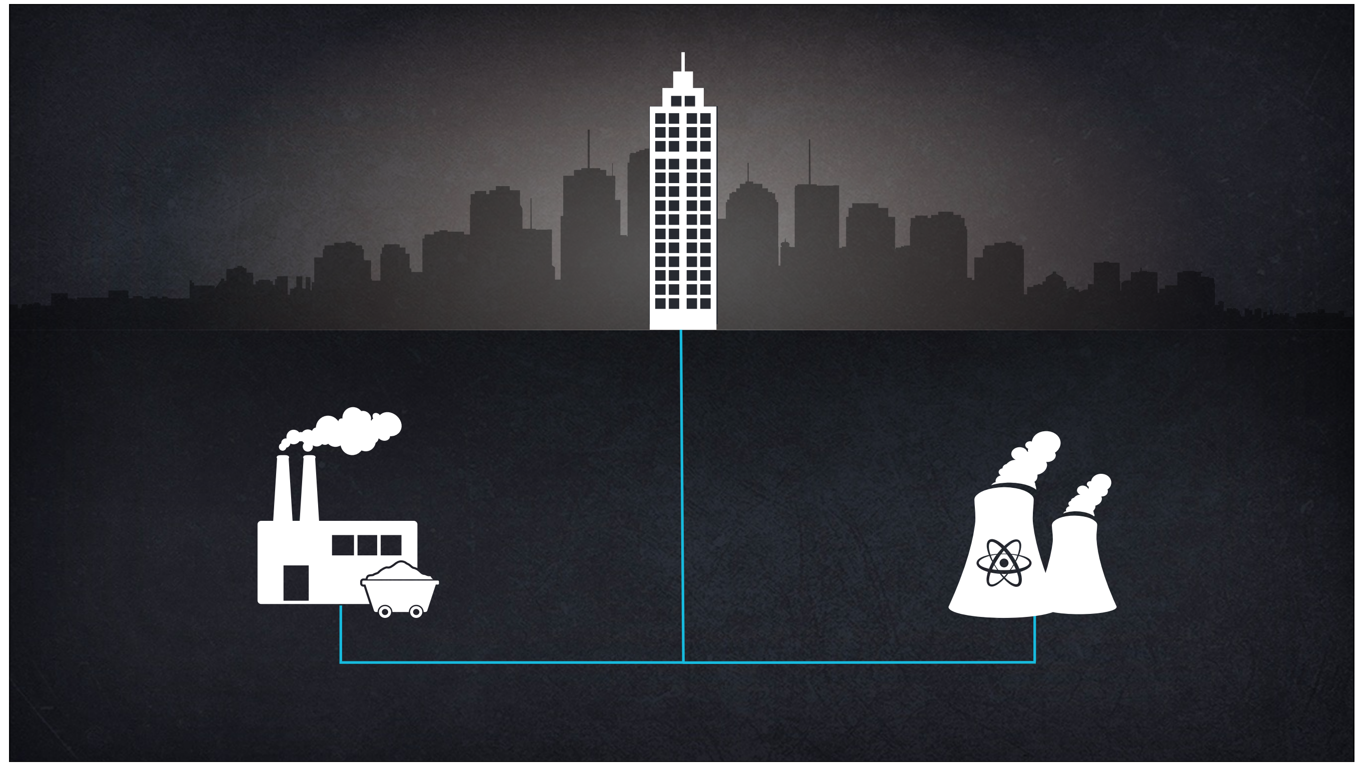
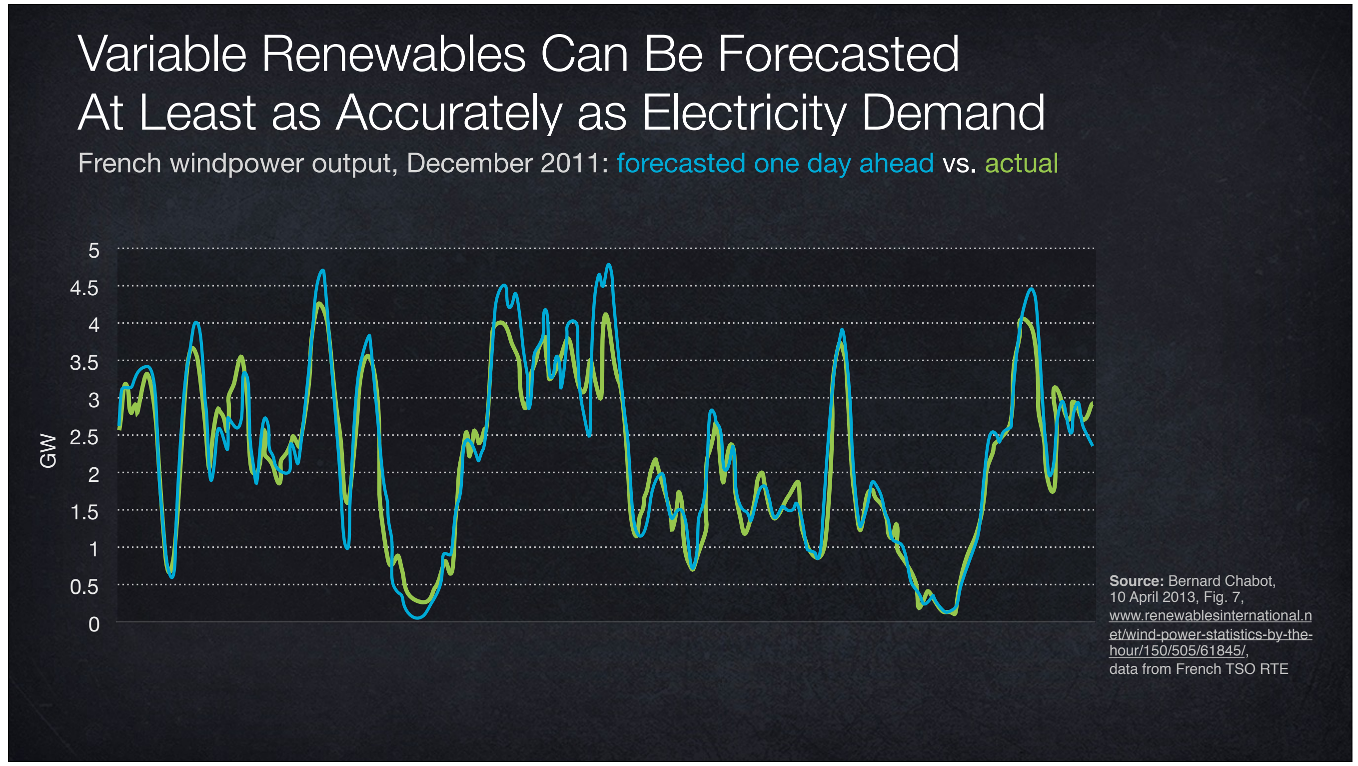


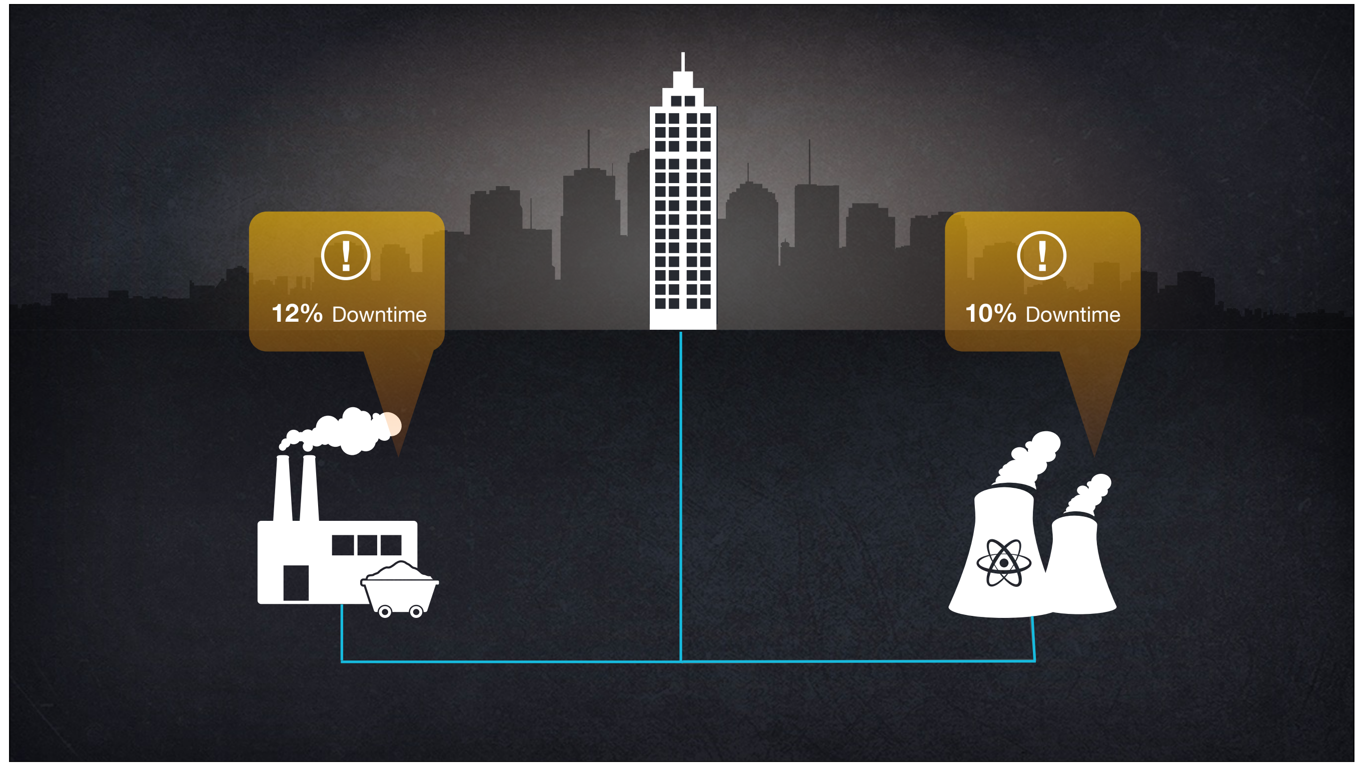
When renewables get cheaper, we buy more, so they get cheaper, so we buy more. Such expanding returns keep outrunning forecasters, as in these forecast fans from the International Energy Agency—raised 5x for windpower and 19x for PVs (which two days ago were again raised by more than a third), yet still falling short of reality. In 2016 alone, modern renewables, excluding big hydro dams, added 139 GW, 55% of the world's new capacity, and they got $242 billion of asset investment, ⅔ of it private. *



Yet we’re still told that only coal, gas, and nuclear stations can keep the lights on, because they’re “24/7,” while windpower and PVs are “variable” and hence unreliable. *

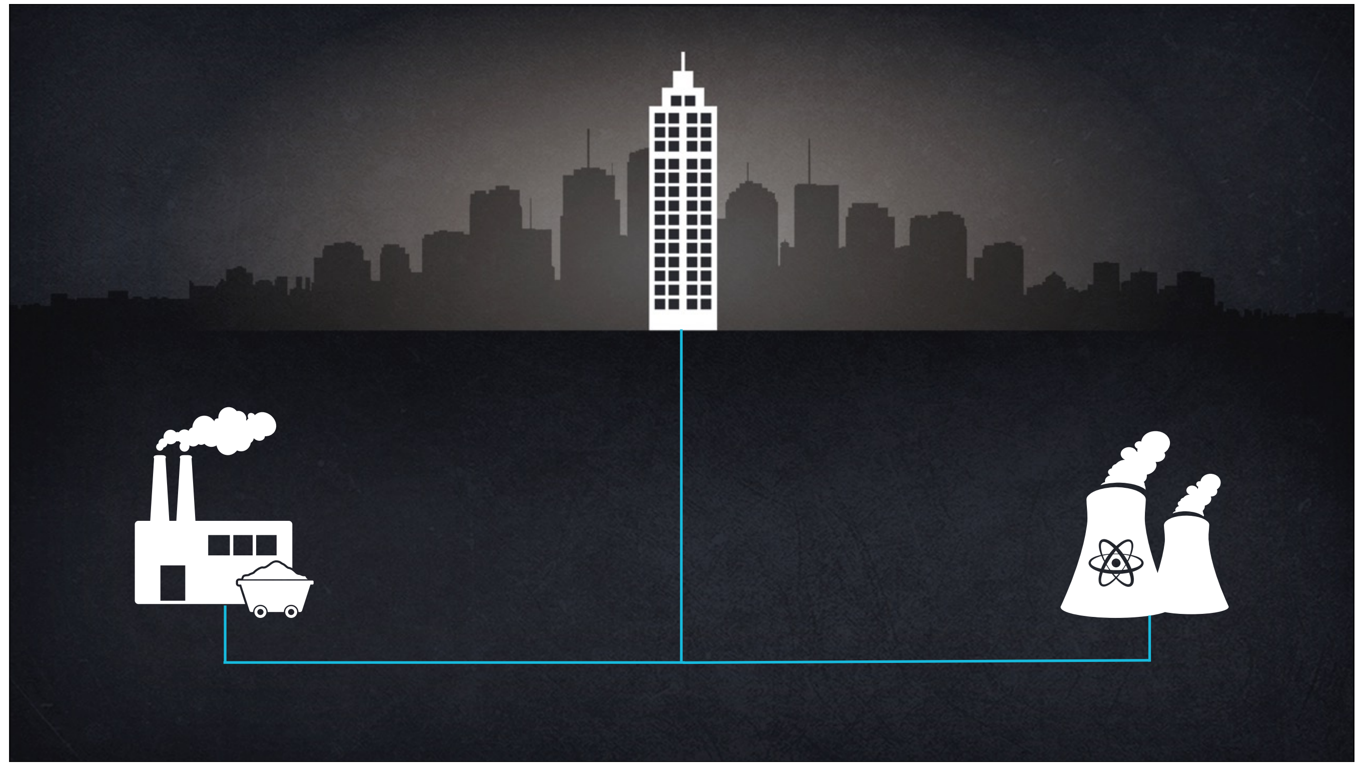


But “variable” doesn’t mean “unpredictable.” Here’s how accurately the French grid operator in one stormy winter month * forecast a day ahead the * output of the country’s windfarms. I’ll bet they wish they could forecast demand that accurately! *



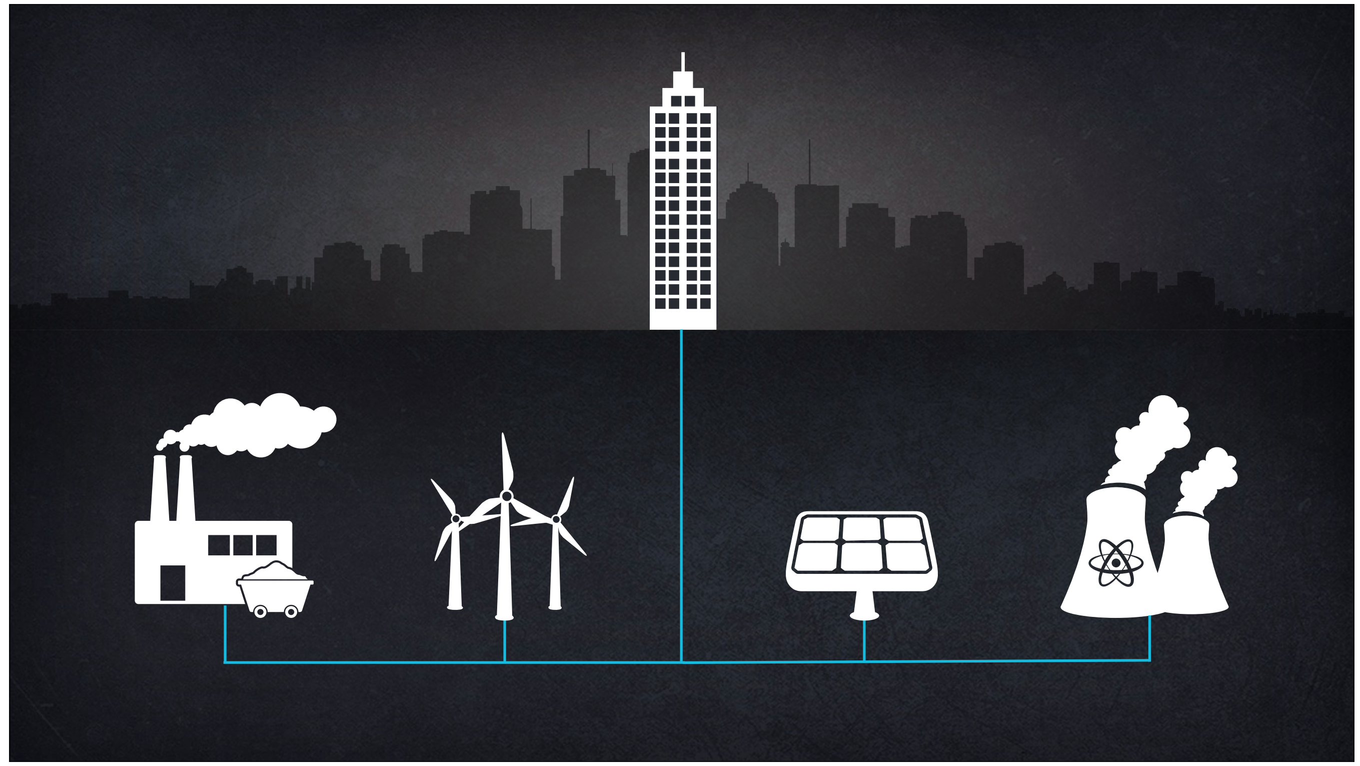
Indeed, we *built* the grid *because no* generator is 24/7. Giant * plants fail too, losing * a billion watts in milliseconds, often abruptly and for weeks or months. * Grids manage this intermittence by backing up failed plants with working plants, * and in exactly the same way, but often at lower cost, grids can manage the forecastable variations of solar and windpower…. *

[automated transition continues...]



[and in exactly the same way, but often at lower cost, grids can manage the forecastable variations of solar and windpower]…by backing up those variable renewables with a portfolio of other renewables, all forecasted, integrated, and diversified by type and location. So in Texas... *

[adjust length of animation if needed—can't continue to slide 51 until animation ends]



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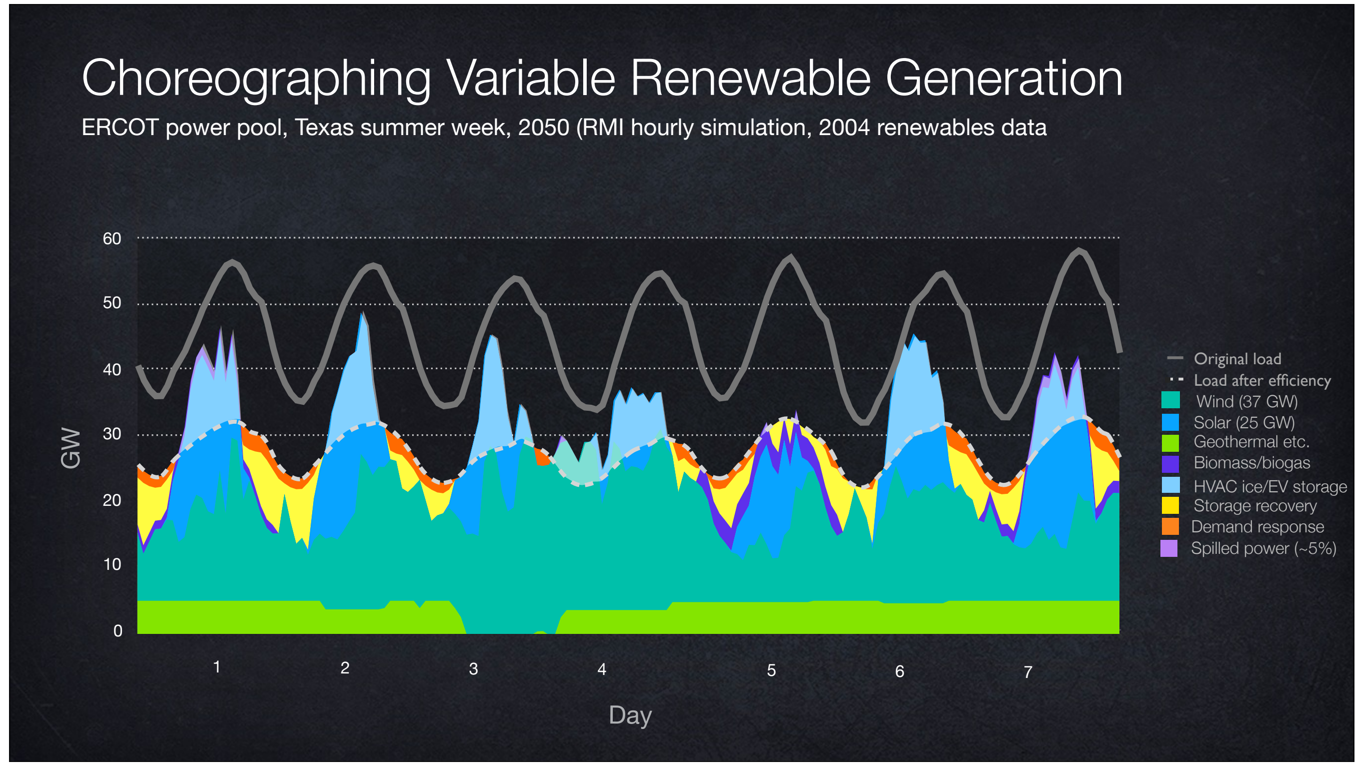
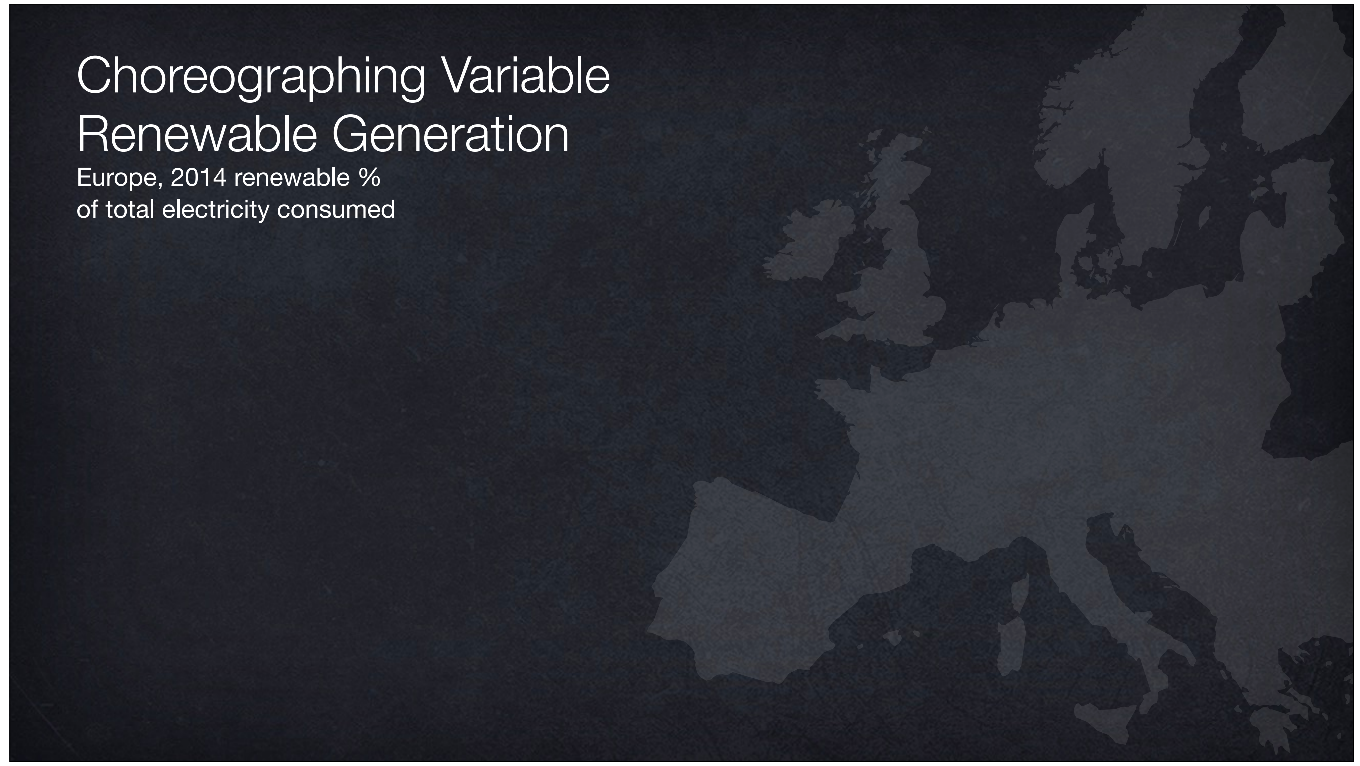
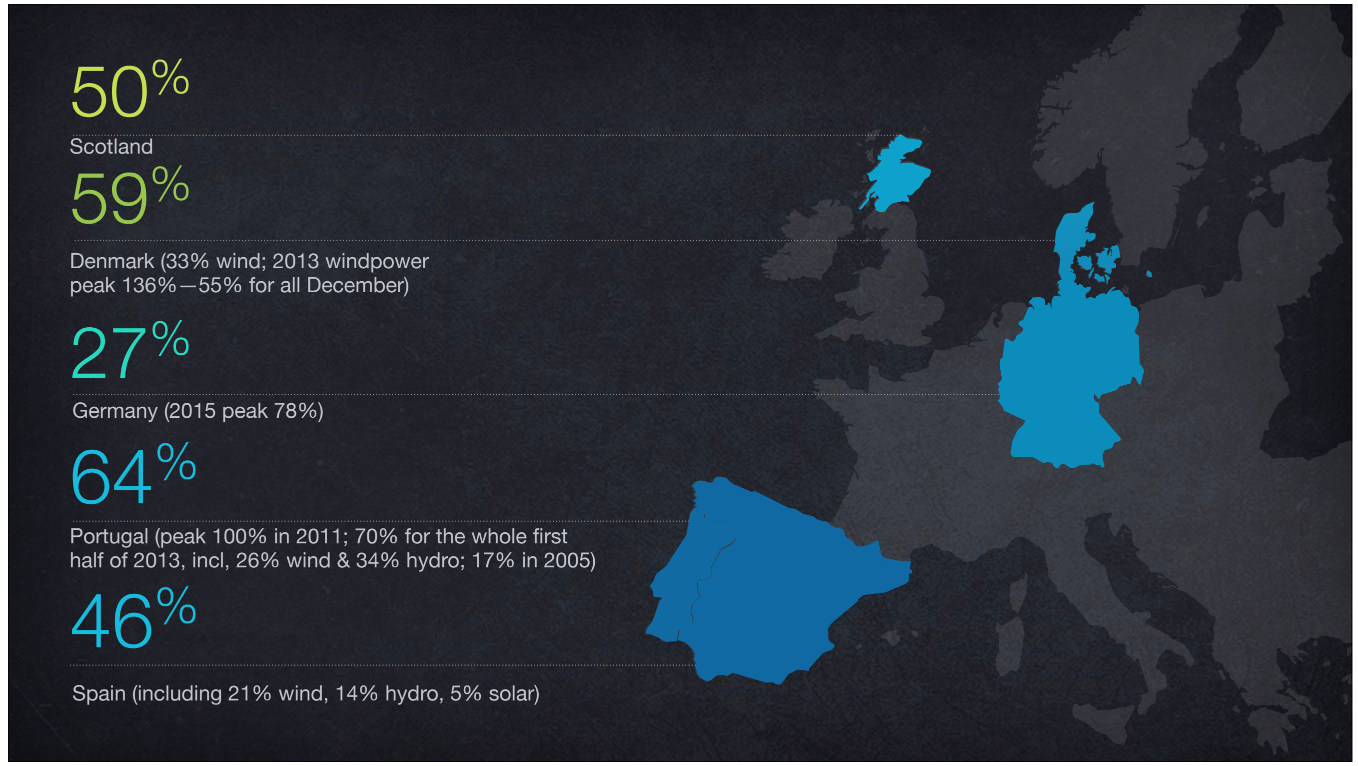


...whose * grid has no big hydro dams and is not connected to the rest of the United States, a 2050 summer week's expected loads can get much * smaller and less peaky with efficient use. Then we can make 86% of the annual electricity with * wind and * PVs, and 14% from * *dispatchable* renewables, * including burning feedlot biogas in existing gas turbines. This 100% renewable supply can then match the load by putting surplus electricity into * two kinds of distributed storage worth buying anyway—ice-storage air-conditioning and smart charging of electric autos—then * recovering that energy when needed, and * filling the last gaps with unobtrusively flexible demand. * Only ~5% of the annual renewable output is left over, so the economics should be juicy. *



Some grid operators do this today. * In 2014, Germany met 27% of its annual electricity needs from renewables, Italy 33% [, Ireland 20%, France and Britain 19%]. * But four *other* * European countries with * modest or no hydropower met about * *half* their electricity needs from renewables, adding no bulk storage and with superior reliability—for Denmark and Germany, ~10x better than ours. In 2015, the ultrareliable former East German utility [50Hertz] got 49% of its electricity from renewables, ¾ of them PVs and wind. The operators have learned to run these grids as a conductor leads a symphony orchestra: no instrument plays all the time, but the ensemble continuously makes * beautiful music. *



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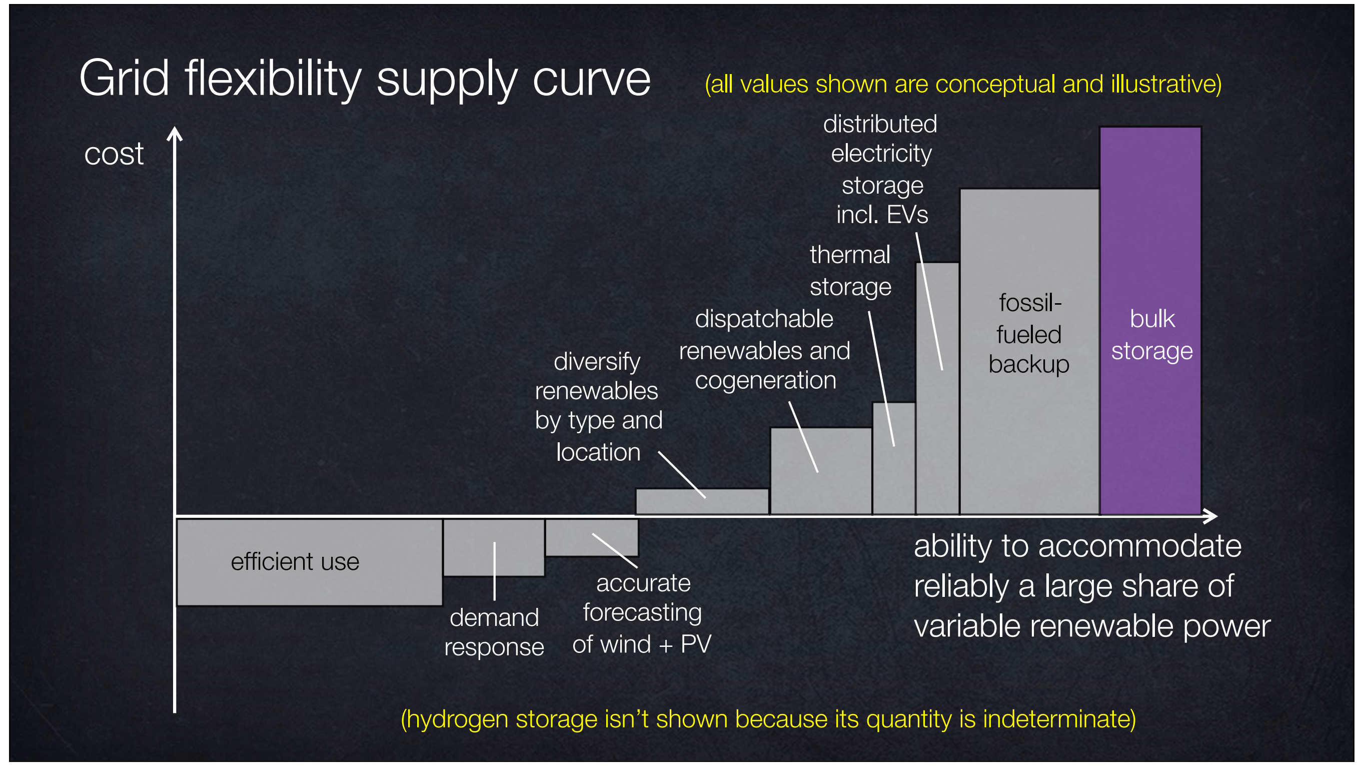
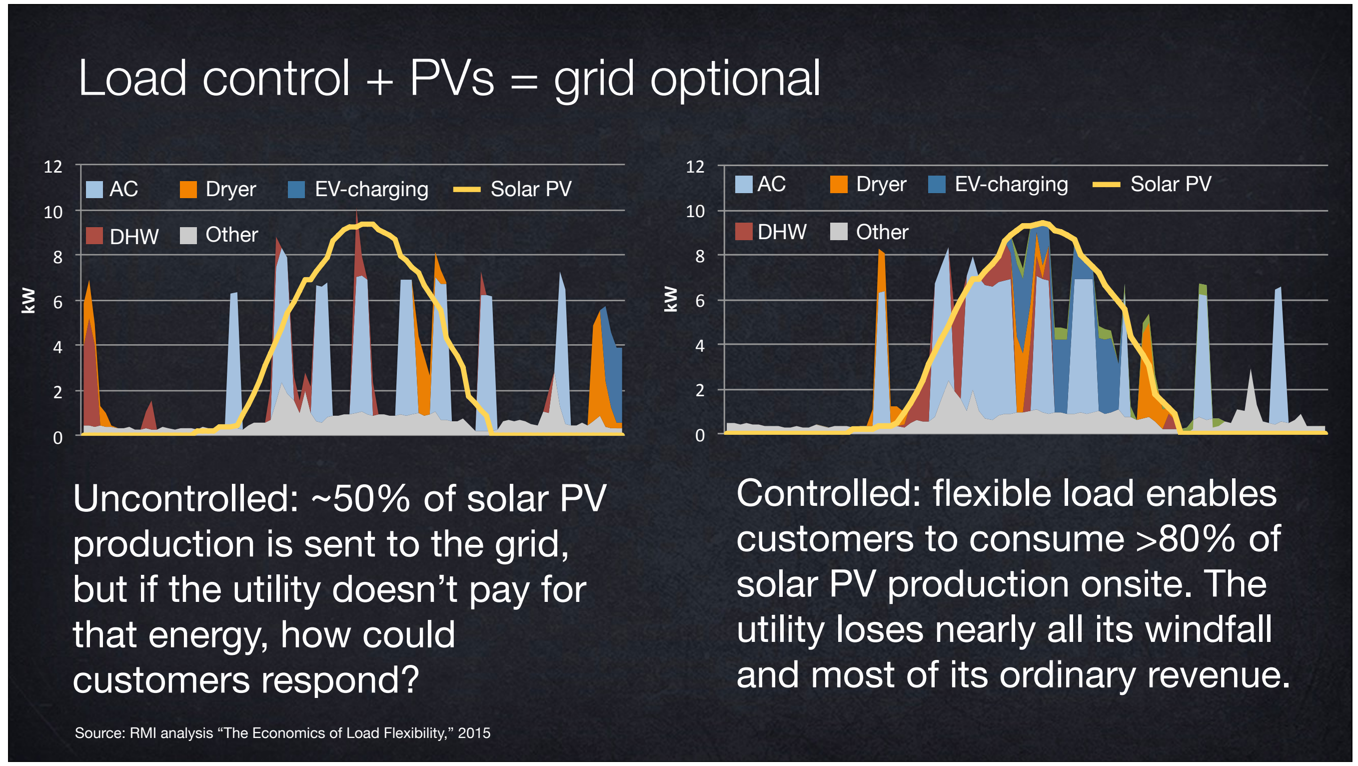
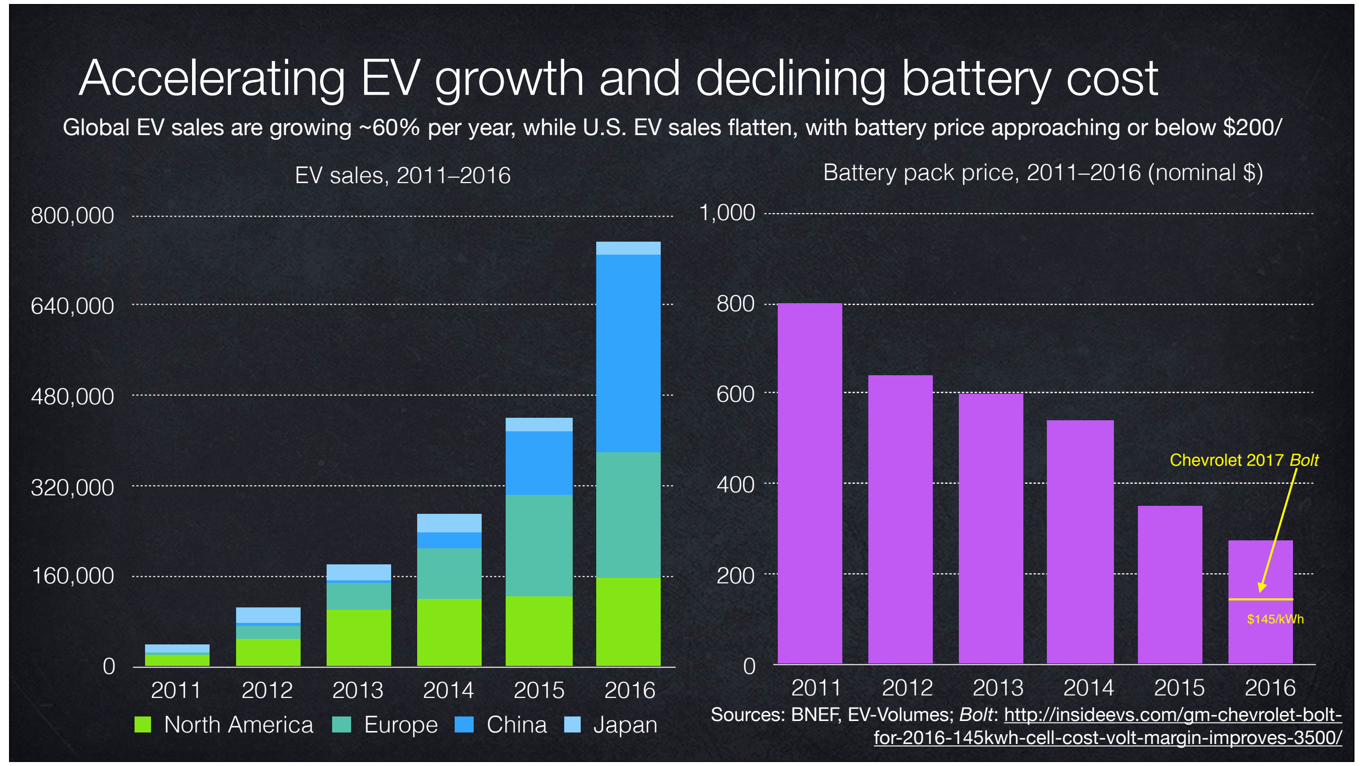


So we have not just one way (bulk storage, in magenta) but about ten ways to make the grid flexible and renewable, sketched in order of increasing cost. Your actual costs will vary, but bulk storage comes last, not first, so we needn't wait for a storage miracle, and the market isn't waiting. *



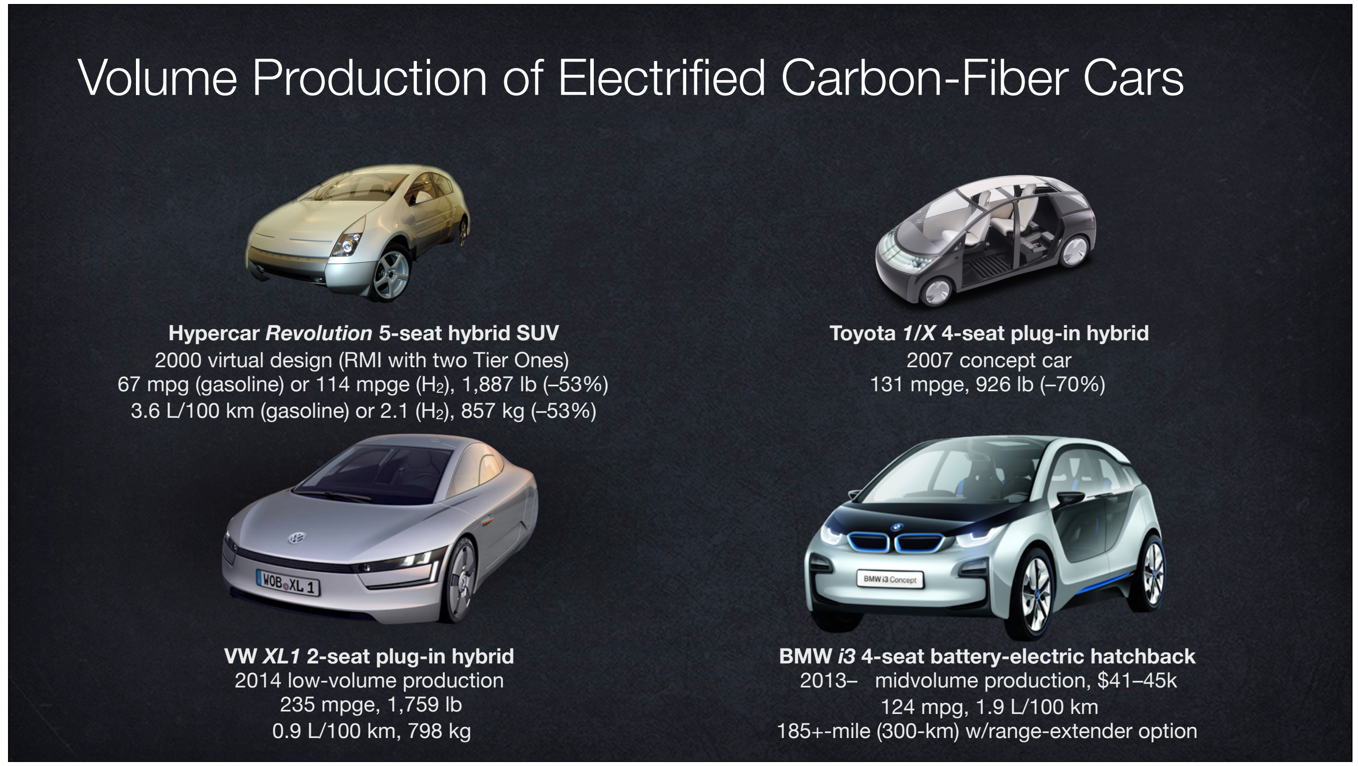
* Adding flexible loads can give customers more market power than suppliers. A typical Hawai‘ian household uses appliances at various times of the 24-hour day, roughly half while rooftop PVs are operating (the yellow curve). But the utility, having tried and failed to prohibit solar hookups, wants to confiscate leftover solar production without paying for it. * Angry customers will probably use smart appliances to move 80–90% of household loads conveniently into the solar hours, costing the utility nearly all its intended windfall *and* most of its ordinary revenue. So this anti-solar tariff, like all six we’ve studied, is a well-aimed boomerang that will actually speed and expand solar adoption by educating and annoying the customers so they leave the grid faster!
Next, to make the grid an optional convenience, just add electric vehicles.*



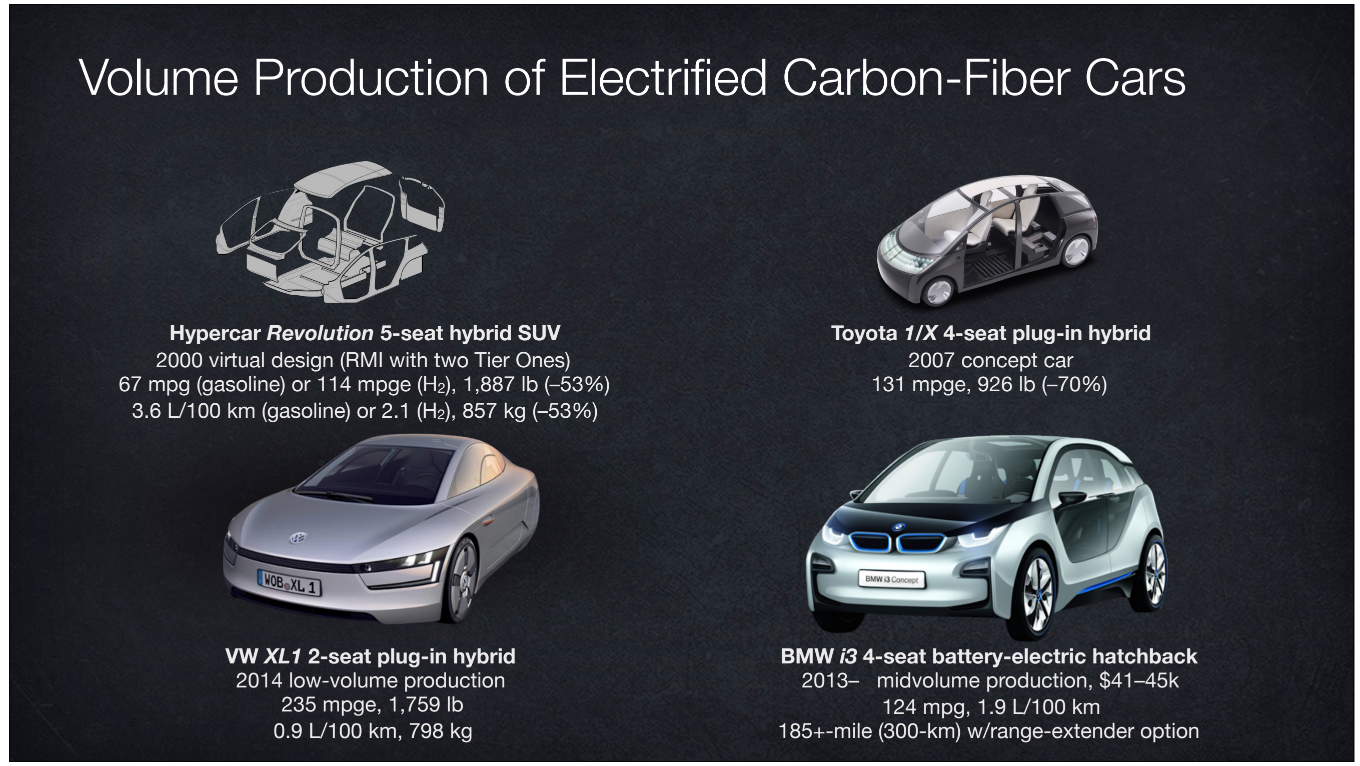
Electric mobility increases grid flexibility while saving money, oil, air, and climate. Global electric-vehicle (EV) sales grew 60% in 2015 and 42% in 2016—when China sold more EVs than the world sold in 2014, and launched 10x growth during 2015–20. Bloomberg expects EVs to save 2 Mb/d in the next 6–8 y—enough to re-crash oil prices as new frontier projects come onstream—then save 13 Mb/d by 2040 (9x ExxonMobil's top forecast; they can't both be right). The forecasts didn't count India, Germany, and Holland targeting 100% EVs *by 2030,* nor fully count four EV accelerators:

- ultralighting, which saves up to ⅔ of the costly batteries;
- feebates, which have helped make ⅓ of Norway's new cars electric—50x the U.S. share;
- monetizing EVs' value as a grid resource, worth enough to repay up to half their total cost; and
- shareable, autonomous, and mobility-as-a-service business models whose high asset utilization strongly advantages electric traction. *

As batteries' nearly 4x (*GM says 5x) price drop in 5 y continues, driving EVs to sticker-price parity in the 2020s, battery production will near 1 TWh/y, bringing abundant cheap batteries, distributed solar everywhere, gas-industry distress, and vast distributed storage and demand flexibility. *



Electrification is much faster and cheaper if we first make autos 2–3x more efficient. The carbon-fiber electrified cars that I invented 25 y ago, we * designed 17 y ago, and Toyota * used our methods 10 y ago * to design as a 2–3x lighter PHEV, * entered the market in 2013. The one I drive is * already profitable for BMW, which says its carbon fiber is paid for by needing *fewer batteries*. An improved manufacturing process that an RMI spinoff developed and sold to a Tier One can now make a complex 2x2m carbon-fiber part in one minute. Making all U.S. autos this way would save 1.5 Saudis or 0.5 OPEC at a cost <$10 per saved barrel, because the ultralighting is approximately free—paid for by a two-thirds-smaller propulsion system and by * radically simpler automaking with 80% lower investment. *



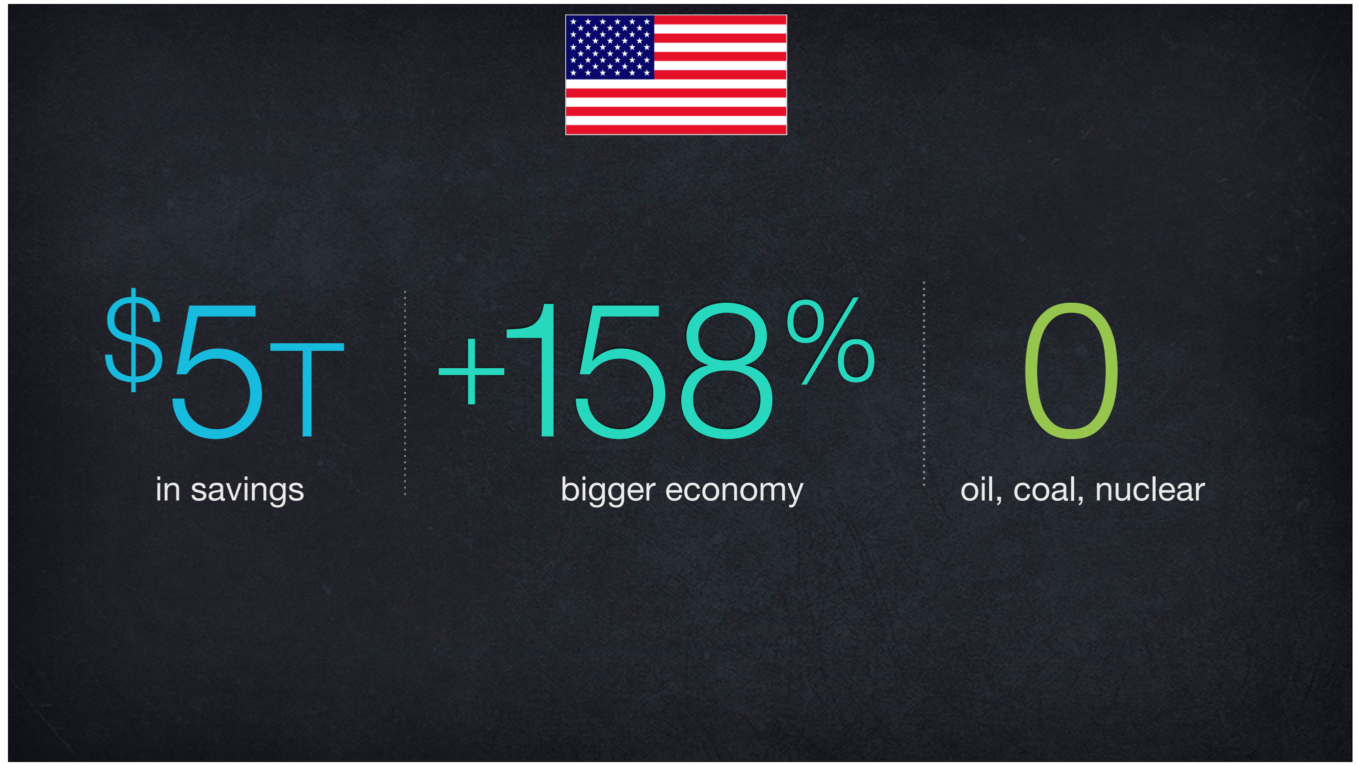
Electrification is much faster and cheaper if we first make autos 2–3x more efficient. The carbon-fiber electrified cars that I invented 25 y ago, we * designed 17 y ago, and Toyota * used our methods 10 y ago * to design as a 2–3x lighter PHEV, * entered the market in 2013. The one I drive is * already profitable for BMW, which says its carbon fiber is paid for by needing *fewer batteries*. An improved manufacturing process that an RMI spinoff developed and sold to a Tier One can now make a complex 2x2m carbon-fiber part in one minute. Making all U.S. autos this way would save 1.5 Saudis or 0.5 OPEC at a cost <$10 per saved barrel, because the ultralighting is approximately free—paid for by a two-thirds-smaller propulsion system and by * radically simpler automaking with 80% lower investment. *

Meanwhile, as the U.S. nears “peak car” in the next five years, autos are morphing from PIGS—Personal Internal-combustion Gasoline Steel-dominated vehicles—to * SEALS—Shareable Electric Autonomous Lightweight Service vehicles. That’s two changes in technology and three in business model, all simultaneous and mutually reinforcing. *

Meanwhile, as India and China radically speed the global mobility revolution, the U.S. is nearing peak car ownership in the next five years, IT-enabled public transit is rapidly improving, and cities are starting to get redesigned around people, not cars, yielding the same access with two-thirds less driving and one-third less concrete. *

Even heavy trucks and airplanes can profitably become 3–5x more efficient, all sped by the military efficiency revolution. Together, just the 2010 version of these savings will shift nearly $1 trillion NPV from oil companies' top lines back to American customers' pockets, and get America off oil.

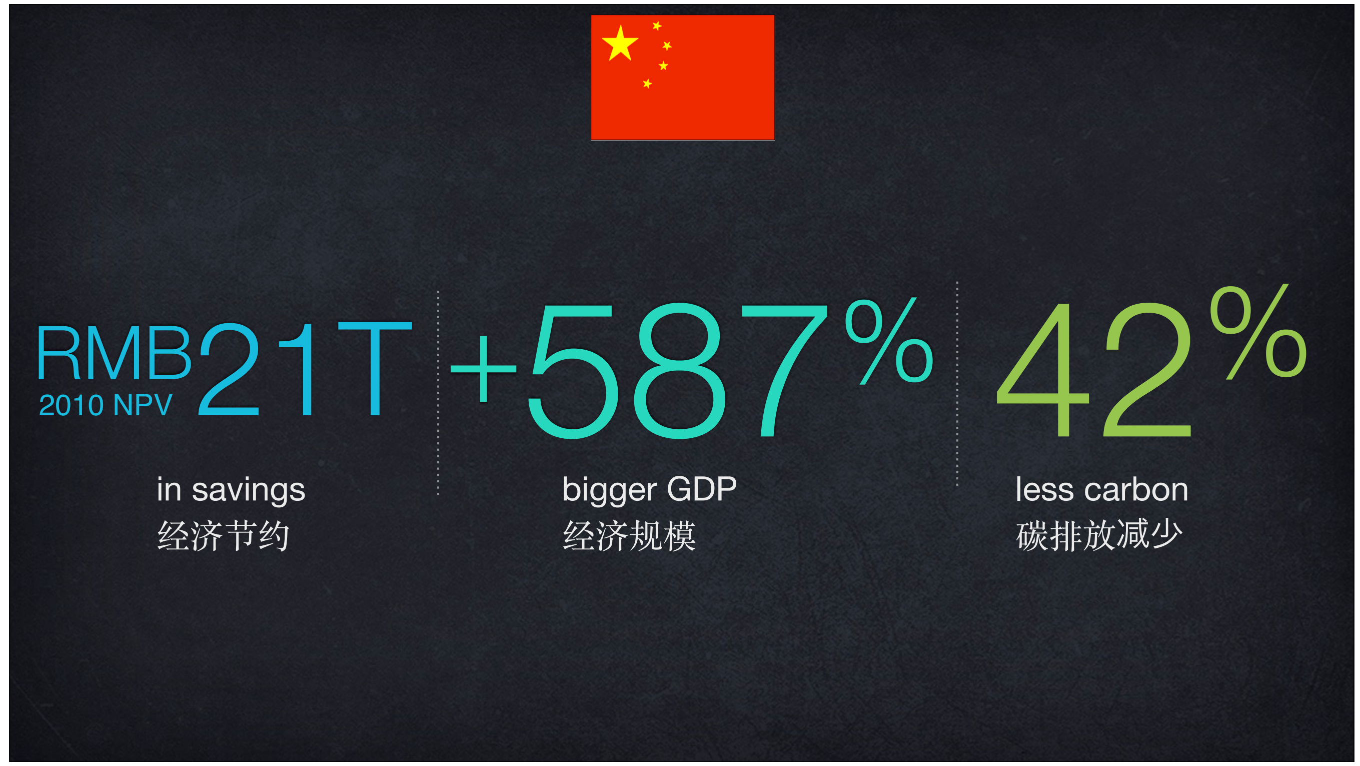
Even before viable EVs and PIGS-to-SEALS emerged, our synthesis *Reinventing Fire* * rigorously showed how to triple U.S. efficiency and quintuple renewables by 2050, needing no oil, coal, or nuclear energy and one-third less natural gas… *



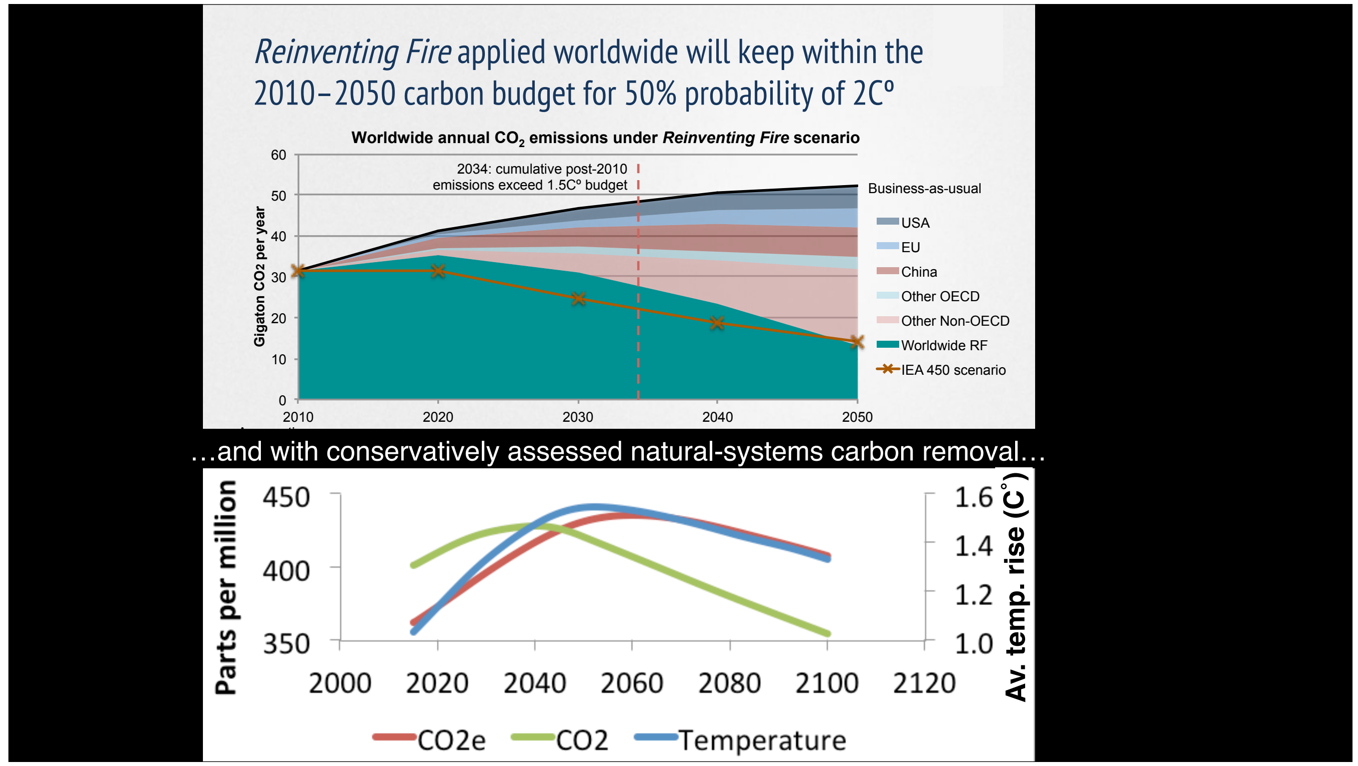
….while saving $5 trillion, growing the economy 2.6-fold, strengthening national security, creating millions of new jobs, and cutting fossil carbon emissions 82–86%—yet needing no new inventions nor Acts of Congress, but with smart city and state policies, led by business for profit. That market-driven implementation is on track. *

These best buys are also the most * effective * solutions to * big *global* * problems [—like * climate change, * nuclear proliferation, * energy insecurity, and *energy poverty—] that hazard *every* country's security and prosperity. And if you like *any* of Reinventing Fire's outcomes, you could support this transition without needing to like *every* outcome or agree about which outcome is most important. Focusing on outcomes, not motives, can turn gridlock and conflict into a unifying solution to our common energy challenge. *

At the G20 a year ago, the Energy Research Institute of China's National Development and Reform Commission published its roadmap for China's energy revolution, aided by Berkeley Lab, Energy Foundation China, and Rocky Mountain Institute. *



It details how China can save ~$3.4 trillion, run a 7x bigger economy in 2050 than in 2010 while using only as much energy as today (but 7x more productively), shift supply 67% off fossil fuels [(83% in the electricity sector, with 69% of generation coming from renewables]), emit 42% less carbon, burn 80% less coal, and get 13x more GDP from each ton of fossil carbon. This roadmap strongly informed the 13th Five Year Plan. *



If we extrapolate these on-track U.S. findings and adopted Chinese findings to the *other* half of the world, cross-checking against similar European results, the world could achieve a ~2C° climate trajectory while providing the same or better energy services ~$18 trillion *cheaper*. * Reinvesting in natural-systems carbon removal could get to about a 1.5C° trajectory, still with trillions of dollars left over, plus huge hidden benefits, especially for the UN Development Goals. Making climate protection not costly but profitable should simplify the politics. *

[Assumptions:

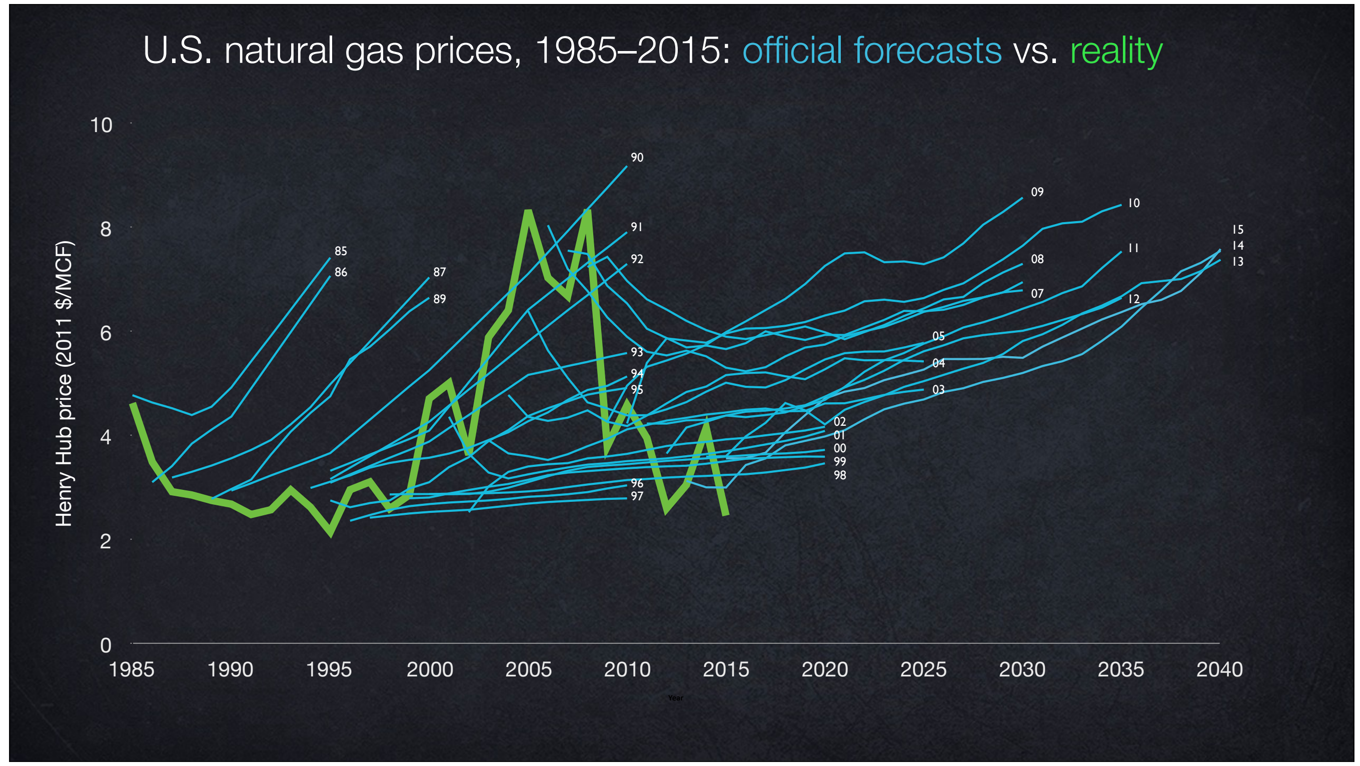
- CO2 emissions are calculated using RF:US, RF:C, and EU Roadmap 2050. Other OECD is calculated from US and Other Non-OECD from China RF trajectories.
- CO2 budget is calculated by ETH Zürich from IPCC data and assumptions for non-CO2 emissions to define an energy-related CO2 budget.
- Cumulative CO2 emissions 2010–50 under RF scenario are 1121 GT by 2050, 79 GT below the 1200 GT 201050 carbon budget for 50% probability of ≤2C° av temp chg, but 331 GT above the ≤1.5C° budget.]

Both hydrocarbon and electricity suppliers face existential risk. Their managers understandably focus on the need for * price to exceed cost. But many forget the *other* part of the business condition: that * *value must exceed price*. If competitors offer a superior value proposition and grab your revenues, it doesn’t matter if you can profitably sell what your ex-customers are no longer buying. Managing this risk is a formidable leadership and organizational-change challenge: as Jack Welch said, “If the rate of change on the outside is greater than the rate of change on the inside, the end is near.” *

And when that value proposition changes, markets can flip with breathtaking speed, as Tony Seba illustrates. * On [New York's] Fifth Avenue, in 1900 you have to look hard for the * first car, then * *just 13 years later* you have to look even harder for * the last horse—if there even *is* a horse. The horse-and-buggy industry thought it had many decades to adapt, but Henry Ford's Model T got 62% cheaper in 13 years [1908–21]. Car-owning households soared from 8% to 80% in a decade [1918–28], three-quarters [in 1928] financed by GM and DuPont's "car loans." Today PV modules just got *80%* cheaper in *five* years; three-fourths of rooftop solar is innovatively financed; Ford's and Edison's industries are merging! / Horse-and-buggy thinking is dangerous but still common: as the late ex-oilman Maurice Strong said, "Not all the fossils are in the fuel." But DuPont's ex-Chairman Edgar Woolard reminds us that firms hampered by old thinking "...won't be a problem, because they simply won't be around long term." They're forgetting that the *pace of transformation is set not by incumbents but by insurgents* uninhibited by incumbents' business models, legacy assets, or cultures. And *investors* flee even before customers do. Capital markets keenly sniff out disruption. Once they think you're in or even headed for the toaster, they don't wait for the toast to get done before they decapitalize you and invest in your successors. *

One last thought. Today's energy transformation isn't just fundamental; it's *ele*mental. The first Industrial Revolution was the Age of Carbon, creating our prosperity—and the world's mightiest industries—from coal and oil and gas. But now the obsolete Age of Carbon is giving way to the modern * Age of Silicon. Silicon microchips, telecommunications, and software turn people from isolated to networked and systems from dumb to smart. Silicon power electronics make electricity interconvertible and precisely applicable, replacing fiery molecules with obedient electrons. And silicon solar cells enable the ascent of energy from mining the fires of hell to harvesting the breath and radiance of heaven. *

Each of you can help make it so by not protecting the old energy system but enabling the new. Thank you all for your good work and your kind attention. *



Natural gas is no longer a safe haven for oil companies either—it just goes away more slowly. Efficiency, renewables, and cogeneration displace natural gas for generating electricity. Together these three non-fossil-fuel competitors got *$650–700 billion* of global investment in 2013 alone. They often beat even the most efficient gas-fired power plants just on *operating* cost. Their advantage widens further if we count the market value of gas's price volatility, ~$2–3/GJ, for fair comparison with efficiency and renewables, which deliver at a constant price for decades. Gas-fired heat will also be gradually displaced by efficient buildings, smarter industrial processes, and solar process heat.
* For 30 years, U.S. wholesale gas prices (green) have been unrelated to official gas-price forecasts (blue)—a warning against buying gas-fired power plants based on spot price. Gas prices' inherent volatility complicates risk management and deters finance. So the new story about abundant and affordable energy for the long haul is less about the fracking that produces ⅔ of U.S. gas than about its inexhaustible, benign, carbon-free, stably priced physical hedges—efficiency and renewables—that are outpacing and increasingly outcompeting it. *

We're told that U.S. energy is permanently recommitting to fossil fuels thanks to a flood of cheap natural gas from fracking shale. This graph shows the abysmal track record in forecasting wellhead gas prices over the past quarter-century, by comparing actual prices in green with official forecasts in blue. Three times just in the past 15 years, investors have lost immense sums by believing those forecasts, including over $100 billion on mistimed combined-cycle power plants. We're told, "This time it will be differ-ent." But basic financial economics tells us that in reality, fracked gas is not cheap—only misdescribed. To compare it fairly with a constant-price asset like efficiency or re-newables that has no fuel, hence no fuel-price volatility, you must add to the gas's bare commodity cost the long-term value of its price volatility, doubling its effective price.
/ History also suggests that if abundant fracked gas *were* cheap at the wellhead, it would create supply-demand imbalances—through the petrochemical pivot, LNG export, and downstream infrastructure constraints—that would paradoxically tend to *in*crease gas's price volatility to customers. (Sure enough, gas prices last February spiked to almost $8.) Consistent with this view, the futures market tells us that gas in a decade will cost about $6–8, not $2–3. That's partly because markets equilibrate: if you want $6–8 gas, just assume $3–4 gas and use it accordingly. But fracking has about eight important risks or uncertainties^ that will take at least a decade to resolve. If they all turn out well, we'll be glad to have more and cheaper gas, but if not, we won't be unduly disappointed, because we won't need so much gas anyway! // So there *is* an important new reality of abundant and stably priced resources for the long haul, but that story is less about natural gas than about their inexhaustible and carbon-free physical hedges—efficiency and renewables. These are so abundant and affordable that our energy future is not fate but choice, and... *
^Output decline, water (quantity & contamination), transparency/additives, methane leakage, induced seismicity, maturation of regulation & science, dry-gas economics