CHALLENGES TO CLEAN ENERGY, Part 1
Where the Sun Never Shines
Intermittency and Renewable Energy

Solar photovoltaics (PVs) and wind may seem like the best friends of environmentalists who want to take quick action to reduce harm caused by conventional fuels. In a very literal sense, however, these energy sources are "fair weather friends," because their power is not always produced when needed. They are *intermittent* (irregular and to a degree unreliable) as opposed to *dispatchable* (provided immediately when demand requires it).

Almost all solar systems installed on buildings in the U.S. are grid connected. They are "fixed" systems set at one angle the entire year, not tracking systems that point toward the sun's angle at a given time of day to maximize energy harvest. Most are fixed to maximize power collection since that is how these systems generate the most power and earn the most money. However, in Texas, this does not assist the electric grid much when power is needed most.

Building-mounted PVs generally produce their peak power at High Noon. Utilities in Texas peak at between 4 and 6 PM in the summer, and around 7 AM in the winter.

Theoretically, PVs can allow a home to be self-reliant. In reality, a home using average amounts of electricity would be severely challenged to do this both economically and logistically. When Austin has a week of rainy, almost sunless weather, which generally happens at least once a year, PV output can fall to as low as 1% of rated output. Will the stand-alone home size its solar system for 100 times its average power needs? Will this home fill its garage with batteries, which are quite expensive at even minimal sizes? Will it have an inefficient noisy back-up generator that relies on expensive, polluting fossil fuel for this time period (which will have your neighbors brimming with joy)?

If you vault past these first hurdles, go further and ask how many survivalists will cut back their use by 25%, or 75%, on these and other days or weeks. Will they use flashlights and cut off air conditioners to minimize power use? Will they monitor the system every day, or several times a day? Will they have access to a quick repair service if their home energy system blacks out?

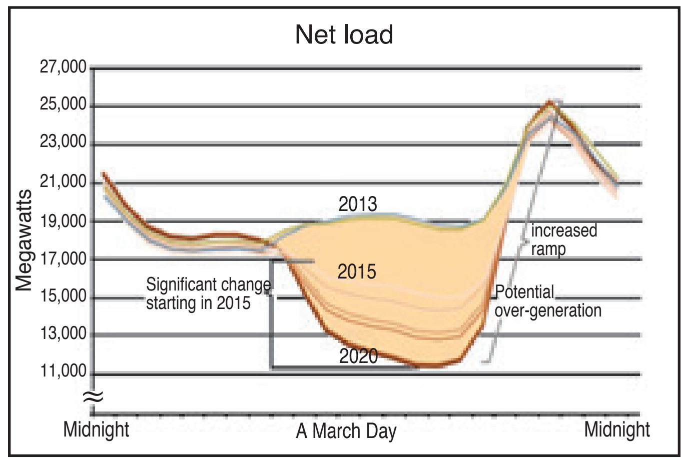
Integrated solar/storage systems will have their place in the new energy future. However, it will probably be to integrate with and enhance the existing grid during critical (and expensive) periods of peak generation, or for emergency back-up. It will not generally be used to support rugged individualism. The grid, then, becomes the ultimate storage battery.

Solar Energy and the Loch Ness Monster

Now assuming that electric consumers and utilities continue to install more solar capacity, and still want the convenience of the grid, there are going to be real challenges, or consequences, to system reliability.

Below is a chart created by the electric system operator for the state of California (CAISO) that is now quite famous in utility circles. It shows the effect that deepening increments of solar energy have, and will have in the future, on the state's electric demand profile. It models utility-scale, as opposed to rooftop, solar cells that more closely correspond with peak demand.

On a March day, you can see solar energy's contribution (tan) building up incrementally under the green line of demand from about 8 AM until 4 PM when it peaks, after which the solar cells produce less power as the day progresses to the point of nightfall. As years progress and more solar energy is placed on the system, the tan gap between the green line of system load and net load with solar gets even larger.



Given its shape, some call it the "duck curve" because it resembles the shape of a deep belly with a rising neck. Others call it the "Nessie curve" because it resembles the shape of a much larger mascot, the Loch Ness Monster. Similar concerns pervade wind generation as well.

iStock.com/Matt84

Nessie *(Shot on location)*

There is a profound difference, however, between this curve and the Monster: grid intermittency is real. Solar and wind generation are weather dependent. Any utility with a similar profile will have to adjust to this phenomenon to provide system stability. This may require expensive electric storage batteries, less-expensive but bulky thermal storage, fast-ramping natural gas plants, or large amounts of "demand response" such as temporarily turning off electric water heaters, to balance intermittency.

Utility scale solar and wind will often also require expensive transmission systems to bring it from one part of a system, or state, to another. Texas, for example, created its CREZ lines (Competitive Renewable Energy Zones) from North and West Texas to the Dallas-San Antonio corridor at a cost of $7 billion.[1] As wind expands and utility-scale solar begins to make increments, renewable energy transmission costs will inevitably increase.

The "ultimate question" is: What percentage of intermittent renewable electricity can the grid handle? This is particularly pointed at Texas, since the state lacks the geology necessary for any large amount of (currently economic) dispatchable renewable energy available in other places – hydroelectricity and geothermal power.

Searching for Nessie

In the past, experts have made a general estimate that an electric system can integrate 25% intermittency *on an annual basis*. At various times of day and year, the percentage of intermittent power the system can absorb can be much higher than 25%. However, to achieve higher percentages on an annual basis may require overbuilding intermittent power sources way beyond affordability.

If you always had to size a wind farm to provide the highest system peak demand at its lowest wind output, and had no storage, then the wind farm would be overproducing ("spilling") most of its power for most of the hours in the year.

It is instructive to look at how some of the world's renewable electricity leaders attained such a high degree of integration. To do this, you have to look at the full context. How much is intermittent vs. dispatchable? How much does it cost? How much can the situation be compared to where you live?

What you will find is that, while there are impressive examples and lessons that have been learned, no country or utility has truly solved the problem. It is an ongoing search.

Hawaii

Kauai Island Utility Coop (KIUC) serves about 33,000 customers (about 67,000 people) on the 4th largest island in the state of Hawaii. Due to its tropical climate (with abundant sunlight), mild temperatures (at least 74% of the households did not heat their home in 2013), and local energy resources, KIUC has attained one of the largest shares of intermittent electric power in the world – but it can only do it briefly, and with relatively high electric prices.[2]

The Coop can get as much as 75% of its midday needs from photovoltaic power, both from rooftops and utility-scale systems, for about 2 hours a day. Another 15% is supplied by dispatchable renewable power from a biomass burner and hydroelectric plants. The remainder is supplied by dispatchable oil-burning power plants.

The intermittent PVs are buffered by an expensive 10-MW battery bank that supplies short bursts of power (a few seconds in length) until the oil-fired generators can ramp up to fill the gaps.

However, this is at midday with fair weather. The island's peak demand takes place in the evening, when only about 18% of 2016 power was provided by the dispatchable biomass and hydropower. So consequently, only about 37% of *total* 2016 electricity was provided by renewables.[3]

All this comes at a price. Since the island's power is still predominantly oil-fired, its *retail* power costs (including power plants and the grid that supplies customers) are typically 30 to 40¢/kwh. (As a comparison, Austin's average residential retail electric cost in 2016 was about 11¢/kwh.) KIUC customers therefore have a higher tolerance to higher-priced renewable energy than the mainland U.S.

In an unprecedented expansion of renewable energy in the U.S., KIUC has signed a 20-year contract with national battery company Tesla to provide a 13-MW central solar array backed by as much as 4 hours of firm battery storage to meet part of its night-time peak. This will come at a wholesale price of 13.9¢/kwh beginning in 2017. Texas ERCOT (Electric Reliability Council of Texas) wholesale costs were 4.1¢/kwh in 2014 and 2.7¢/kwh in 2015.[4]

While there are currently several hundred Megawatt hours of battery storage around the U.S., almost all of this is experimental, or is cost justified as "ancillary services" (such as quick ramp up to fill in power gaps). The KIUC project is the first solar/battery storage system in the U.S. that will be competitive with wholesale power supplied by the utility it serves, albeit a high-priced one.

Denmark

This small Scandinavian country has a territory only 16 times the size of Travis County. Despite a population 5 times more than our county, the country only consumed 160% more electricity than Austin Energy customers in 2015.

In 2014, the Danish electric system had one of the largest percentages of renewable electricity in the European Union. Approximately 41% of its power supply came from intermittent renewables (39% wind, 2% solar PVs), another 12% came from biomass, biogas, and solid waste.[5] (Wind production actually increased 8% in 2015.)

Half of Denmark's electricity comes from renewable energy, but it comes with a steep price.

Further, many of the plants that biomass is burned in are extraordinarily efficient. (They use as much as 90% of available heat as opposed to 33% for older coal plants). They are Combined Heat and Power (cogeneration) systems that generate electricity and reuse the waste heat to serve urban areas with piped-in district heating.[6] Their efficiency is magnified further because many of these plants have onsite thermal storage. This allows them to throttle down in times of high intermittent wind supplies while still providing essential heating needs, becoming de facto spinning reserve (generators that run at low power to be quickly ramped up or down with changing demand).

While about half of the country's electricity does indeed come from renewable energy, it comes at a steep price, and with some curious trade-offs.

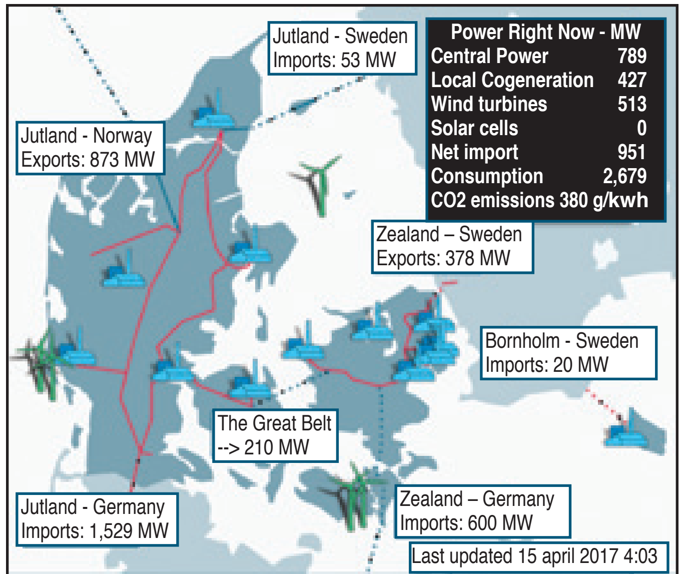
Denmark has among the highest residential electric prices in the world. In 2013, it was 39¢/kwh, compared to Austin, at 11¢/kwh, and the average U.S. price of 12¢/kwh.[7] The largest part of this cost is value-added tax that has nothing to do with the real price of electricity. Still, the cost to operate the system was about 17¢ per kwh, and the combined high cost and taxes are a strong deterrent to consumption.

About 30% of the country's biomass electricity is fueled by garbage incinerators. Though the country recycles a high percentage of its solid waste overall, its *household* recycling rate was only 22% in 2013.[8] Paradoxically, the more the country recycles, the less fuel it has, which raises the price of power from the incinerators since they run less often. Denmark actually imports some garbage from other countries for fuel.[9]

The toxic ash produced by these incinerators is also a problem, with high concentrations of dioxins and furans from plastic combustion, as well as heavy metals from objects such as batteries.

About 21% of the country's remaining biomass power (both electricity and heat) is from locally sourced straw pellets. The remainder is from wood, with about 50% of this imported from other countries. Several of its large coal plants, as well as some of its combined heat and power plants, have been converted to operate with wood pellets. In 2013, the country used an estimated 2.3 million metric tons of wood pellets, virtually all of which was imported.[10] Most of these imports came from other European counties, though about 2% came from the U.S.[11]

The majority of the high cost of wood and wood pellets is subsidized by the Danish government in order to limit (and eventually eliminate) coal to lower the country's greenhouse emissions.



Screen-shot of real-time map for Denmark energy systems operator keeping track of imports and exports. Watch moment-by-moment electric trading online at http://energinet.dk/EN/El/Sider/Elsystemet-lige-nu.aspx

While these various factors have allowed Denmark to be a leader in renewable energy, the largest reason for its high percentage of intermittent wind and solar power is that it trades electricity with its neighbors. It has several large high voltage transmission lines that connect to the larger Scandinavian grid. It trades intermittent renewable power and surplus cogeneration with Norway's hydropower, Sweden's hydro and nuclear power, and Germany's renewable and coal power. Given that winter is Denmark's peak season, it exports more electricity in winter (due to district heating operations) and imports more electricity in summer.

On July 9 of 2015, Denmark produced more than enough wind power to supply its entire demand. At one point (3 AM), it produced 40% more than it needed.[12] This was all absorbed by the neighbors.

Overall, Denmark's electric use represents a small part of the collective use of these 4 countries. In 2015, the overall percentage of *intermittent* renewable energy (not dispatchable hydro and biomass) for these 4 countries was only about 19%.[13]

SCANDINAVIAN INTERMITTENT RENEWABLE ELECTRICITY 2015

	All Consumption Terawatt Hours	Wind/Solar Terawatt Hours	Percent Intermittent
Germany	563,630	126,318	22%
Sweden	135,537	16,666	12%
Norway	129,768	2,815	2%
Denmark	33,630	14,734	44%
TOTAL	862,565	160,533	19%

Seen from a distance, Denmark's example is both inspiring and discouraging at the same time. This tiny country is setting an example for the world, but the results cannot be duplicated where similar geography, peaceful neighbors, and tolerance for higher-priced power do not exist.

Iowa

Transmission lines (purple) allow Iowa to trade electricity with other states.

The state of Iowa also generates a high share of electricity from intermittent wind power – 32% in 2015.[14] The majority of the balance comes from coal, with gas and nuclear also contributing. Unlike Denmark and KIUC, the state's retail electric costs resemble those in Texas.[15] Similar to Denmark, it appears that the state can do this because the state trades power with bordering states. Iowa generates 20% more electricity than it consumes.

Norway

Norway also differs from Denmark and KIUC by obtaining almost all of its electricity from renewable energy at moderate costs. Norway produced about 97% of its electricity from hydroelectricity in 2014, with residential prices below the average U.S. price, even after taxes.[16]

Costa Rica

During the Paris climate talks in December 2015, this small Central American country was toasted as a role model for the world. In 2015, about 99% of its electricity was generated by clean energy. However, in 2012, the country received 88% of its total generation from dispatchable renewables, with about 5% coming from wind and solar, and the rest from oil.[17] While more intermittent wind and solar power have been built since 2012, the country's electric system will be bolstered by the new 306 MW *Reventazón* hydroelectric dam that came on line in 2016.[18] It is currently the largest hydro plant in Central America.

In June 2016, the country's residential electric rates began at 13¢/kwh for minimum consumption levels, and quickly rose with higher use to 21¢/kwh.[19]

Iceland

Iceland received 71% of its electricity from hydropower in 2014, with the balance coming from geothermal power.[20] Its industrial electric rates are so low that several aluminum smelters have moved to the island to take advantage of them.

Geothermal heat is provided to most households through district heating systems harnessing both low-temperature resources and waste heat from high-temperature geothermal electric plants. In 2014, the costs for most residents ranged from below-average to average U.S. heating fuel prices.[21]

Iceland's renewable electricity potential is 2 to 3 times its current use, with so much available that the UK and Western European counties are considering importing some of it through a proposed "IceLink" high-voltage DC line under the sea.[22,23]

Other Countries

Virtually all other countries that have a large percentage of their electricity coming from renewable energy rely on dispatchable power to accomplish this.[24] Some notable examples are below.

OTHER COUNTRIES WITH HIGH PERCENTAGES OF RENEWABLE ELECTRICITY

Country	Percent Renewable	Type of Renewable
Austria	78%	66% Hydro; 7% Biomass; 4% Wind
Brazil	84%	76% Hydro; 7% Biomass; 1% Wind
New Zealand	74%	54% Hydro; 14% Geothermal; 1% Biomass; 5% Wind
Paraguay	100%	100% Hydro

Germany

Germany is not at the forefront of world countries in terms of absolute percentages of renewable electricity on its grid. In 2015, it obtained 35% of its electric power from renewables; 22% of total electricity was from intermittent wind and solar power. However, in many respects it has led the world with its Energiewende ("energy transition") policies for a gradual conversion of all sectors of its energy use (including electricity, heating, industry, and transportation). The country intends to both reduce its overall energy consumption and to convert its consumption to renewable energy for most of the balance.

The Energiewende had its roots in the Oil Crises price shocks of the 1970s and the antinuclear movement during the same time period, which was exacerbated by alarm many Germans experienced by the meltdown of the Chernobyl nuclear plant in 1986.

Environmental protection is the largest motivation for this direction towards renewables; other important goals include enhancing national security and improving the economy.

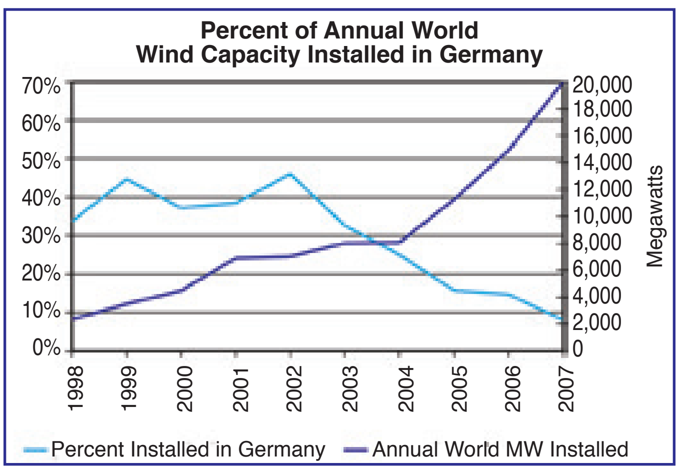
Much has been written to both praise and lambaste this vanguard effort. There is much to learn from Germany's programs about what to do, and not to do, in advancing a renewable electric system in other countries.

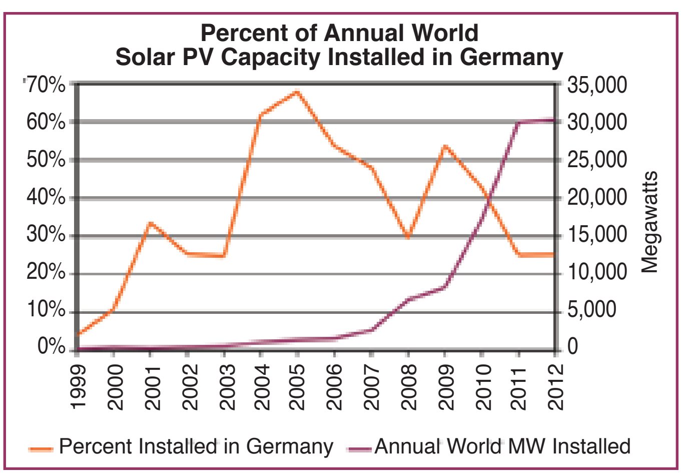
Positive Effects

1. Single-Mindedly Lowered the World Cost of Renewable Energy – In 1991, an electric tariff went into effect that guaranteed a 20-year price to reward investment in renewable energy. The price could be adjusted downward every year for new investments in that year, but would be kept in place for investments already made. These tariffs were large enough to prompt more renewable energy investment in Germany than any other country. From 1998 to 2004, between 25 and 46% of all wind capacity in the world each year was built there.[25] From 2001 to 2012, between 25% and 68% of all solar PV capacity in the world each year was installed there, despite a cold and cloudy climate more resembling Alaska than Texas.[26]

The tariff created an anchor market that launched a learning curve that has reduced the cost of wind and solar energy to the point where it is today. Had it not been for Energiewende, worldwide development of these renewable sources would have easily been delayed for several years (at a minimum).

In 1997, there were 2,089 MW of wind power in Germany.[27] (There was so little wind capacity in that era that even this small amount was over a quarter of all the wind generation in the world.) By 2015, Germany had over 45,000 MW of wind installed.[28] In 1996, there were only 11 MW of solar power in the entire country; in 2015, there were 39,698 MW.[29]





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2. Environmental Protection – Germany is attempting to phase-out all nuclear power stations by 2022 and is intending to achieve an 80% reduction in fossil fuel use (including but not limited to electric generation) by 2050 with energy efficiency measures and renewable energy sources.[30] The risk of nuclear accidents, nuclear waste disposal, and the need to drastically reduce greenhouse gases and emissions from fossil fuels are the biggest motivations.

3. Democratization of Grid Ownership – Most large German renewable energy systems are owned by cooperatives or municipal utilities, not large companies. It is possible for a wind or solar farm to have hundreds of local investors, in contrast to the dominant model in the U.S., which relies on national or international corporations to build and finance the equipment. While it is possible for large utilities to participate in Germany's renewable tariff system, as of 2012, only 5% of renewable electric generation was owned by them, while almost half was owned by citizens, investment pools open to citizens, and farmers.[31] One of the reasons is a higher interest rate for these corporations, but another is lack of motivation to pursue a new business model.

Municipalization of German utilities is also a trend, partially driven by environmental concerns about large corporations' ownership of nuclear and coal plants and their seeming lackluster commitment to alternatives. Since 2007, over 60 municipal utilities have been formed, with 170 communities attempting to purchase at least some part of the grid that serves them.[32] In 2013, Hamburg, the country's second largest city (population 1.8 million), held a successful referendum to authorize the purchase of two privately-owned utilities that served it.[33]

4. National Security Improved – Russia is the largest single provider of natural gas in Europe, and it wields the continent's import dependency as a weapon of influence and political pressure. In 2013, Germany imported 88% of the gas that it used, with 39% of these imports from Russia.[34] Though most of this is used for heating, about 5% of Germany's electricity is produced with this fuel. In 2013, Germany also imported 97% of its oil, 87% of its hard coal, and 100% of its uranium.[35] Reducing these imported fuels enhances national security while strengthening its balance of trade.

5. Employment – About 80,000 direct jobs had been created to install or service renewable energy. (This is net of jobs lost in conventional energy production.) This is expected to grow to between 100,000 and 150,000 in the 2020 to 2030 time period. In 2013, Germany exported about 2/3 of its manufacturing output of solar cells and wind generators.

Hans Weingartz

The Energiewende had its roots in the Oil Crises price shocks and the antinuclear movement during the 1970s. This anti-nuclear protest took place in Bonn on October 14, 1979.

Negative Effects

1. Continued Reliance on Coal – Between 2013 and 2016, the country obtained between 40 and 45% of its energy from coal, despite a growing percentage of renewables in the mix.[36] There are at least 4 reasons for this, some more palatable for environmentalists than others.

First, since utilities are obligated to purchase renewable electricity whenever it is available (with the exception of threats to grid integrity, such as too much power flowing at once), coal plants have become the first resort for spinning reserve to maintain a steady flow of power. These plants are more quickly dispatched than nuclear plants. Gas plants, while highly efficient, less polluting, and more quickly able to ramp up and down, have much higher fuel costs than in North America.

Second, due to Germany's national policy of nuclear phase-out for safety reasons, which has already retired some of the reactor fleet and will retire the rest by 2022, there is a shortage of baseload power. In the short-term, this is likely to grow (the safety of coal plants themselves not withstanding).[37]

Germany's government began the phase-out of nuclear power in 2006. The plants began retiring as they aged, with no nuclear replacement. However, this phase-out was accelerated in 2011 following the meltdown at the Japanese Fukushima plant.[38] By 2015, nuclear generation fell to about half of its level in 2006.

The third reason is that a lot of German coal power is exported to other countries to make up for lost corporate utility sales to renewables in their own country.

And fourth, lignite (soft coal) mining still supports many jobs, which will be lost when these plants stop operating.

2. No Stable Profits for Fossil Fuel Plants – Due to the preference for renewable energy, coal and gas plants run less often, and do not make as much money. This makes it hard for them to make a profit, even though the system would crash without their contribution.

3. No Stable Profits for Storage – It should be noted that coal plants are not the only conventional electric facilities having financial problems because of the renewable dispatch priority. Germany has several "pumped hydroelectric" facilities that can store intermittent renewable energy or cheap nighttime power by pumping water in a lower reservoir up to a higher one to rerun the fluid through a hydroelectric generator. It is a relatively economic way to store large amounts of power, but Germany has no tariff that guarantees that these facilities will earn a profit.

4. High Rates/Energy Poverty – Germany has one of the highest residential electric rates in the world.[39] In 2013, it was 38¢/kwh, compared to 11¢/kwh in Austin and 12¢/kwh in the U.S. Germany's cost was only slightly lower than Denmark's. German rates in 2015 were twice what they were in 2000,with about 20-25% of the cost attributed to renewable energy. This pain is particularly acute among the nation's poor.

This surcharge may go down over time as older 20-year tariffs for higher cost wind and solar power are replaced with newer, less expensive contracts resulting from economies of scale. However, the cost mitigating effects of these newer contracts may be reversed by purchases of offshore wind power, which is much more expensive than land-based sites.

These higher costs do have the effect of driving down consumption, another goal of Energiewende.

5. Renewable Surcharge Exemption to Large Commercial Customers – Large industrial customers have been specifically exempted from the renewable energy surcharge. This was intended to allow domestic, energy-intensive industries to better compete on the world market. Over time, however, the exemption has been expanded to large customers where high-cost electricity is not critical to competitiveness.

6. Need for Transmission Upgrades – The country is in need of transmission and distribution upgrades, much of it driven by expanding renewable energy. If this is not done, renewable electric generation will increase the amount of spilled (wasted) power that cannot be utilized. For instance, offshore wind farms built in a sparsely populated northern part of the country cannot sell their power to the southern part without new lines. While this is not a technical problem, it is an expensive one, with one estimate of 8.2 billion Euros.

7. Expensive Offshore Wind – In many parts of the world, building a wind plant offshore can increase electric production per wind turbine because of stronger and more consistent resources. However, this comes at a hefty premium, currently about 175% more than land-based sites.[40] By 2015, 4,608 MW of German wind power were commissioned, under construction, or approved in the Baltic and North Seas, with another 6,680 MW planned[41].

It is expected that the price will fall with more completions, but this learning curve will probably be costly.

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Again, the Energiewende is a comprehensive effort that deals with all sectors of Germany's energy use. The focus of this article is about electric generation; it has not discussed building codes, transportation, and heating to any degree. These are essential in any long-range plan for clean energy. Electricity, however, is a good starting point given Austin's municipal ownership of its utility and its decades-long commitment to efficiency and renewable power.

The current limits of intermittent renewable energy technology and costs constrain their use to a fraction of total power needs. Moreover, even if energy efficiency and smart grid strategies are added to intermittent renewables, and employed at an unprecedented level, it will still take large amounts of dispatchable power to maintain the system.

Another story discusses dispatchable renewable technologies in detail, including those that work today, and some more appropriate technologies for Texas climate and geology that might work in the future.

The reader is cautioned not to read too much into futuristic technologies. With enough R&D money, time, and (corrected) mistakes, some of them may eventually become viable solutions. But new technology development is not entitled to certainty. If it were, the stark problems associated with the conventional power system would already be solved.

Walt Musial/National Renewable Energy Laboratory

Offshore wind farm in Baltic Sea off German coast

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CHALLENGES TO CLEAN ENERGY, Part 2
The Limits of Technology

New clean energy innovations will very likely have a much larger potential than lifestyle changes to mitigate or eliminate global warming emissions. And if you read journals and blogs on clean energy, many writers and reporters are smitten by these innovations' collective potential. Many of these technologies do have the *potential*, over the next several decades, to displace significant amounts of conventional energy with enhanced energy efficiency, renewable energy, and energy storage.

New technology, however, is not flawless, and just because it exists does not mean it is affordable, appropriate, convenient for everyone, or will be adopted quickly.

Look at an example of a breakthrough in electric lighting. In about 1981, inventors were able to adapt microcircuitry in fluorescent lighting ballasts (regulators that adjust the amount of power so that it will not destroy the lamp). These would save 20% of electricity used by these lamps. However, most/all of the first companies that manufactured them went out of business because of high product failure rates. Even though the bugs were worked out, the failures created a stigma that would last for several years, scaring off customers.

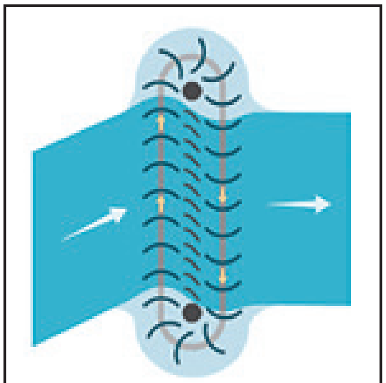
Once the ballasts became more reliable, their savings became so acknowledged that the U.S. Congress passed legislation mandating ballast efficiency standards in 1988 that became effective in 1990.[1] This did not overtly require electronic ballasts, but it strongly encouraged it. Adding to this momentum for adoption were numerous utilities that gave rebates to customers because it was cheaper than buying new power plants, which enhanced the customer's payback for installation. And for all this, as of 2014, the old technology of magnetic core coil ballasts still clung to 10 to 20% of the market.[2]

A federal phase-out on the manufacture or import of most inefficient ballasts finally took effect in 2014.[3] Even then, however, the standards allowed exceptions for niche markets and residential sales. And there are easily tens of millions, possibly hundreds of millions, of old ballasts yet to reach the end of their life.

This is all to say that, in 2016, some 35 years after the first sales of electronic ballasts, they still have not completely replaced dated technology.

Another example of slow-moving innovation in clean energy is a device that can produce electricity cost effectively with small hydroelectric units. Hydroelectricity generates about 7% of electric power in the U.S.[4] While hydroelectricity can theoretically provide 4 times as much power worldwide as it does now, the cost of installing conventional turbines is affected by economies of scale, and it is generally not cost effective to harness water at low drops ("low heads") in elevation.[5]

In the 1970s, a medical doctor-turned-inventor, Daniel Schneider, began perfecting a device that could harness water and wind flows with a flow engine. Looking much like a gargantuan Venetian blind, the slats were curved in such a way that they would be pushed up by the wind and water, which would then flow through the center, and then push the slats down. Advantages included: 1) low-cost assembly; 2) the cost-effective ability to harness power in very low-altitude drops in rivers formerly considered unthinkable; 3) less wind energy lost at high speeds due to limited stress from centrifugal force; 4) and the ability to capture wind from varying directions without turning.



Schneider Lift Translator

Courtesy Natel Energy

It was ingenious. It made the cover of *Popular Science* in February of 1978. It received research money from the U.S. Department of Energy.

While he died in 2011, his mission was continued through Natel Energy, in Alameda, CA. Schneider's son, Abe, is President and CTO, and his daughter, Gia, is CEO. The company went on to develop the hydroelectric version of the invention as a commercial product. The first one began commercial operation in an irrigation canal in Oregon in June 2015. The product also has applications in smaller dams, run of the river hydro, and even for the tail waters of power-plant cooling water outflows.

So from the time of the original patent filing in 1976 to commercial implementation, it only took 39 years.

LEDs were first invented in 1962, and the first niche-market product based on the technology, a red indicator light, appeared in 1968.[6] LEDs did not make their way into the residential lighting market until 2009, and even then at very high (early adopter) prices. As of the first quarter of 2016, LEDs had 26% of the "A-line" (common bulb) market, despite national codes phasing out most conventional incandescent bulbs.[7] This is incredibly impressive, but way short of overnight adoption.

Low-e (low heat emission) windows that reflect heat away from a building in southern climates, and back into a building in northern climates, began with R&D in 1976. The technology progressed relatively quickly, and by 1988, the technology had captured 20% of the U.S. residential market for new windows.[8]

However, even by 2010, low-e windows had only reached 80% of the residential market despite the cost effectiveness of the technology, utility rebate programs to encourage their use, and building-code requirements that effectively mandated them.[9] This is not to mention the majority of *existing* structures that had not installed them through retrofits.

In the first 6 months of 2016, solar cells accounted for 26% of all new electric capacity in the U.S. Solar cells represent the best chance for widespread adoption of decentralized renewable energy in buildings, and are ripe for adoption by the utility sector to displace some level of peak demand.

The first solar cell was developed in 1954 by Bell Laboratories to power satellites in space, and the first cells sold in 1956 for the 2016-equivalent of $15,993 per watt.[10] (Interestingly, cells manufactured in that era are still operating, albeit at reduced levels of output.) By 2016, the cost had fallen to $1.18 per watt.[11]

During the height of the Energy Crisis in the late 1970s, the U.S. Department of Energy's national goal was to have photovoltaics (PVs) down to 5¢ per kwh. That was the nominal benchmark cost of retail residential power (on the customer side of the meter) in 1980. Adjusted for inflation, this would be 13¢ per kwh in 2016. Yet it was not until about 2010 that PVs even reached this price for *wholesale* utility-scale power at megawatt-level economies of scale.[12]

There is no doubt that new clean-energy technology will continue to have a marked effect in the future. However, the vast majority of new inventions and products made from them will take considerable time to reach maturity, few will be adopted quickly, and even when adopted, there will not be universal conversion for a *long* period of time.

Endnotes

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The Leading Edge

Those who read the last story may have the impression that this writer has scant regard for the potential of new clean-energy technologies. This is not the case. While considerable caution is justified, clean energy would never be where it is today if some seemingly far-fetched technologies had not worked. This story will briefly highlight some of the leading edge technologies.

Aerogel Insulation

Insulation is usually rated by thickness. For each inch of a given material, there is an "R-value" or thermal resistance value applied. Conventional insulation is generally rated at an R-value of 2.5 to 3.8 per inch. Aerogel, a high-tech form of insulation developed by NASA for space travel, has an R-value of about 10 or higher per inch. It is said that insulating a house with aerogel would allow a home's winter heating to be done with a candle.

It is one of the lightest materials known on earth, often (literally) 99.8% air, with a base solid surrounding these insulative microscopic air pockets that can be made of various substances, including silica, plastic, and organic matter.

Aerogel has many unique qualities besides superior insulation ability that make it a good building material. It is hydrophobic, so it is resistant to mold, mildew, and decay. While it stops heat transfer, it also "breathes," preventing condensation build-up in building cavities it is used in. It is also effective when compressed, compared to other insulating materials that lose effectiveness under compression.

One such application is to prevent thermal bridging, a phenomenon that occurs in walls, roofs, ceilings, and some floors where heat is lost through wood or metal studs that are difficult to insulate. Attaching thin aerogel strips to the studs reduces these losses. Another use is in the remodeling of historic buildings, which often have little space to insert conventional insulation between walls or floors. This problem is alleviated with a much thinner material.

Future applications, depending on price reductions, may include bolstering the efficiencies of refrigeration cabinets, doors, and attic hatches, and transparent inserts in double and triple-glazed windows.

A company in Singapore, Bronx Materials, has claimed a breakthrough in price reductions, with a factory using recycled paper as the solid base scheduled to open in 2017. As of late 2016 however, there was no indication of cost.

Current U.S. Aerogel Manufacturers

Aspen Aerogels.. (888) 481-5058
30 Forbes Road, Building B
Northborough, MA 01532
aerogel.com

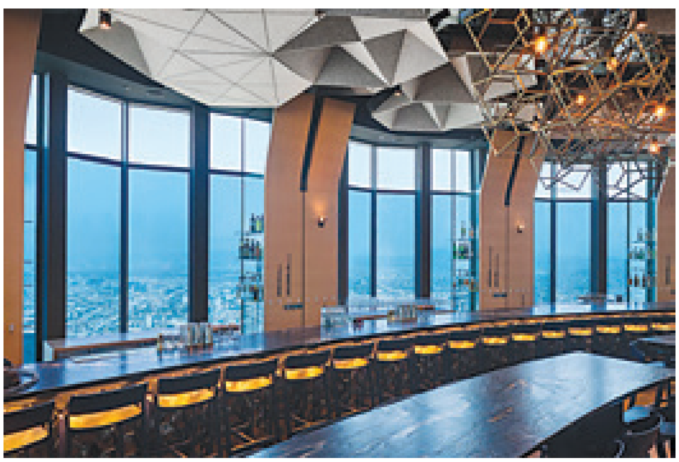
Courtesy Aspen Aerogels

Aerogel strips used for thermal bridging insulation

Cabot Corporation .... (617) 345-0100
Two Seaport Lane, Suite 1300
Boston, MA 02210-2019
cabotcorp.com

Thermablok Inc. .... (813) 980-1400
6900 Interbay Blvd.
Tampa, FL 33616
thermablok.com

Advanced Windows



Courtesy SageGlass

At the 71 Above restaurant in Los Angeles, smart windows filter sun at eye level while allowing more light in at a higher level. They allow optimal views of the LA skyline.

Self-dimming windows – "Low-e" energy saving windows have been commercialized since the late 1980s, and are commonly required by building codes today. They prevent heat from entering or leaving a building, depending on the climate. However, there are penalties too.

For climates in the Southern U.S., low-e windows are manufactured to lower air conditioning bills by preventing heat from entering a home, but they slightly raise the cost of heating in the winter because of the same quality. For the northern part of the country, these windows are built to reradiate internal building heat that would normally try to escape through the window glass, but this causes heat build-up and higher air conditioning bills in the summer.

There are now commercial products that have the ability to dim or stay clear at the discretion of the building's occupants. Known as electro-chromic or dynamic windows, a small electric charge reacts with a special metal oxide coating to tint, or untint, window glass.

This screens out up to 99% of visible light, and 91% of incoming heat. (Alternatively, it can allow 58-60% of visible light and 41% of incoming heat to enter if desired.) It takes from 7 to 12 minutes, depending on weather, to completely tint or untint between this range.

The cost premium for the glass is offset by reductions in the size of air conditioning, elimination of blinds and shading devices, and electricity savings from less air conditioning load and use of natural daylight. (Most large commercial buildings require air conditioning even in the winter.) These windows also improve the aesthetics of the interior space by reducing glare and allowing better connection to outdoor views.

While there is no prohibition against using these windows in residential settings, the price premium will usually not pay for itself quickly.

Dynamic glass manufacturers in the U.S. are listed below.

SAGE Electrochromics, Inc. .... (877) 724-3321
2 Sage Way
Faribault, MN 55021
sageglass.com

View, Inc. .... (408) 514-6512
195 S. Milpitas Blvd
Milpitas, CA 95035
viewglass.com

Aerogel windows – At least one window company, Advanced Glazings Ltd., markets a curtain wall (SOLERA® + Lumira®) for commercial buildings with aerogel insulation sandwiched between 2 panes of glass. While not transparent, it is translucent (looking similar to frosted glass), allowing natural daylighting without most of the heat gain associated with other types of curtain walls.

Advanced Glazings....................................... (888) 452-0464
870 King's Road
Sydney, NS
Canada B1P 6R7
advancedglazings.com

Non-Compression Refrigeration

Since the advent of modern refrigeration in the 19th century, the technology has relied on compressors to operate, which compress gas into liquid refrigerant, that evaporates again as it carries heat out of the refrigerated storage space. The compression cycle has direct energy efficiency losses, which can be compounded when its waste heat increases air conditioning costs.

They are bulky, heavy, noisy, and the vast majority of the chemicals used as refrigerants have adverse environmental effects. The refrigerants in conventional systems in the U.S. (typically hydrofluorocarbons, or HFCs) are highly potent global warming gases. Depending on the particular application, they can trap hundreds or thousands of times more heat in the atmosphere than carbon dioxide.

Phononic, a Durham, NC company started in 2009, has spent $160 million in venture capital and 7 years of R&D effort to perfect a possibly disruptive non-compression refrigeration technology. It uses microchips to dispel heat, increasing storage space and energy efficiency while reducing noise and weight. The chips are aided by passive carbon dioxide circulation in a sealed loop around the case acting as a refrigerant. The chips are manufactured in the U.S., then exported overseas for refrigeration assembly.

As of 2016, the company had sold 3,000 medical refrigerators used for life sciences, medical care, and pharmacies. These units are 10 to 30% more efficient, while having 20% more volume due to the elimination of the compressor. The company also sold 1,500 residential wine chillers, and plans to market a 4.7 cubic foot commercial beverage refrigerator in 2017. These other products also have the benefits of less energy use and more volume.

Phononic has been prospecting the air conditioning market as well. It believes its technology's best economic value lies in zonal cooling and heating, where a central unit would provide a base level of comfort (e.g., 80 degrees F throughout a building, while individual zonal units (similar to portable air conditioners or mini-splits) would hone to the final temperature (e.g., 70 degrees).

Microchip refrigeration is not the only compressor-free refrigeration technology being developed. Cool-Tech Applications, a French company, is perfecting magnetic refrigeration. Running electric fields through certain materials causes changes in temperature. Using this principle, the magnets act as a kind of heat pump, while water circulating through pipes carries heat away from the case.

Cool-Tech has followed a similar path to commercialization, starting with niche markets such as medical refrigerators and wine coolers. It also plans to introduce small beverage chillers in 2017, and is working in collaboration with commercial refrigerator manufacturer Structural Concepts of Muskegon, MI, to create prototypes for grocery stores.

Both Phononic and Cool-Tech have also partnered with Haier (formerly GE Appliances) to commercialize grocery store applications.

There is some departure in their business models, however. Cool-Tech expects there to be a premium for the added expense of magnetic refrigeration components. Though the company expects this to fall over time due to economies of scale, there may still ultimately be a payback period of 2-3 years from energy and maintenance savings to recoup the extra cost. Phononic believes they can break into the market without any premium.

Since these are leading edge technologies, it is hard to predict the future of non-compression cooling and heating. However, this is no longer a fantasy that can be ignored.

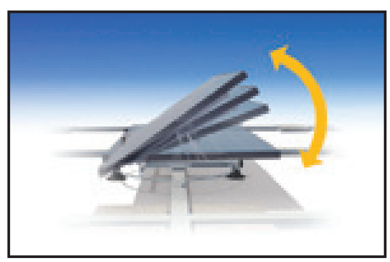
Phononic .... (919) 908-6300
800 Capitola Drive, Suite 7
Durham, NC 27713
phononic.com

Solar Tracking Collectors for Buildings

PVs have become an elegant, soundless, pollution-free way to produce onsite electricity and lower bills. However, while offering a degree of independence, almost all PV systems in the U.S., including Austin, are grid connected. Decentralized PVs are mounted at a fixed tilt that optimizes annual production. While this lowers bills and reduces pollution, it often works at cross purposes with the utility they are connected to.

In Austin, the highest utility demand is in the summer at about 5 in the afternoon, which is when fixed-system production is waning, only producing about 31% of their rated output at that time. This can be compensated for by tilting fixed systems in a westerly direction, but it reduces overall power production in the Austin area by about 10%.

PV systems can automatically track the sun throughout the year for optimal tilt and power production, but tracking systems, up to now, have been too expensive and complicated for decentralized applications on buildings.



A new product, PV Booster, is a 2-axis rooftop tracker designed for flat commercial roofs. It tilts the array to optimize angles, allowing the sun to attain output that better matches the utility's peak demand year round. The company states the technology will produce about 32% more annual electricity than a south facing fixed tilt system, and 47% more power than a west facing fixed tilt system.

While costing more than a fixed array, the extra revenue greatly exceeds the extra cost from increased power. Other positive features include boltless installation (the base is self ballasted by the mounting assembly), light weight, and adaptability to high winds (flattening the panels when they exceed a certain velocity) to protect the arrays from damage.

PV Booster .... (626) 585-6900
130 Union St.
Pasadena, CA 91103W
pvbooster.com

CHALLENGES TO CLEAN ENERGY, Part 3
Throwing Money at Problems
The False Promise of Free Weatherization


Dennis Schroeder, Nat. Renewable Energy Lab.

Austin Energy's low-income weatherization program provides several hundred homes per year with free basic conservation retrofits such as ceiling insulation, solar screens, duct sealing, and air infiltration measures. Since 1982, almost 13,000 households have participated.

However, free weatherization is not free. In 2014, Austin Energy collected about $2.6 million for free weatherization. This was funded with an average surcharge on all residential customers; in 2014, this was about $7 per household.

And what are the poor getting for all this money? Very little. A survey of free weatherization participants in 2011 and 2012 showed a 49-year payback for homes that received building-shell retrofits; it was 59 years if free air conditioners were included.[1]

At first this seems counterintuitive. Why wouldn't there be more savings? Reasons include: 1) lower-income people generally use less energy, so there is not as much energy that can be saved; and 2) many of these homes require repairs before they can be weatherized. This trend of long paybacks has been observed on a national level as well.

Low-income weatherization is largely viewed as a social program, in contrast to most other utility programs designed to save energy cost effectively while stopping pollution.

Charity or Investment?

Whenever you spend a dollar on energy programs, there are choices about how to achieve the best results. Let's look at 3 examples.[2]

- 1. $1 Million in Free Weatherization: 294 participants/$168,000 saved in 10 years.
- 2. $1 Million in Customer Bill Discounts: 397 participants/$1 Million distributed in 10 years.
- 3. $1 Million in Door-to-Door LED Direct Installation Program: 8,327 participants/$3.2 Million saved in 10 years.

The third example has yet to occur in Austin in a major way. But it is one of several ideas that could provide more energy savings and bill relief per dollar invested.

One good example of the direct installation approach is Seattle City Light's Powerful Neighborhood Program.[3] The pilot program was run between 2009 and 2011. It installed 665,000 compact fluorescent lamps and LEDs, as well as 33,000 low-flow showerheads, and 42,000 aerators in 56,000 single-family homes and apartments. (This was about 15% of the utility's residential customers.) The total savings from the program was estimated at 22 million kwh a year, enough to save consumers $2.1 million annually.

The program was targeted to types of customers that had historically low participation rates in the utility's other efficiency programs, including low-income, seniors, and people who did not speak English.

Since the installers were already in these homes, they used the opportunity to conduct onsite energy assessments. This generated immediate recommendations used to enlist these customers in the utility's other energy-saving programs, and provided a database to plan future efforts.

Energy Efficiency in Rental Buildings

In 2015, 49% of the occupied homes in Travis County were rented.[4] Most of these buildings were individually metered, creating a disincentive for the landlord to upgrade them to be energy efficient. With the exception of small portable items such as efficient light bulbs, tenants will not invest in the upgrade of a building they do not own.

This assumes they can even afford to. Between 2011 and 2015, the income of a tenant-occupied household in Travis County was about $41,000, less than half of the estimated $90,000 of owner-occupied households.[5]

Austin had one of the first energy conservation programs in the country to assist tenants in multifamily buildings. Since 1990, tens of thousands of units have been assisted by this program. However, Austin's conservation programs have not been able to affect many single-family rental houses and duplexes. And in recent years, Austin's programs have also failed to affect a change in heating and air conditioning units in apartments.

The savings from reaching this market are profound.

- Air conditioner retrofits can reduce consumption 47-53%.[6]
- Air-source heat pumps can save as much as 58%. (10-20% of apartments can be retrofitted with heat pumps using conventional technology.)[7]
- If efficiency and one-bedroom apartments opt for mini-split systems instead of central ducted units, the savings would be as much as 79-82% on air conditioning and as much as 77% compared to all-electric heating.[8]
- LEDs can save as much as 85% compared with incandescent bulbs.

Facts on Low-Income Energy Use in Austin

• In 2016, a venerable energy research organization, the American Council for an Energy Efficient Economy, released a study of "energy burdens" in metropolitan areas of the U.S.[9] This showed the percentage income spent on energy costs for households at 80% or below of Average Median Income. The study revealed that households in the bottom 40% of income in the Austin metropolitan area spent 5.5% of their income on electricity and gas, compared to 2.7% for the average of all the region's households.

However, of 48 metropolitan areas in the study, Austin ranked as relatively affordable, with the 9th lowest energy burden for lower income households. Of the 5 metro areas in Texas analyzed, Austin ranked the lowest.

• Austin has a Community Benefit Charge line item on the utility bill which funds energy efficiency, solar energy, $10 million in bill discounts for the low-income residents, and street lighting. In 2014, residential customers in the bottom half of income paid about $10 million for this Charge. They received $17.3 million in benefits.[10] This estimated 70% surplus was paid for by commercial customers and households in the upper half of income.

• In 2014, Austin Energy exceeded all major utilities in Texas ERCOT electric system in money collected per customer given to customers in the bottom half of income for energy assistance and conservation.[11] It achieved this while attaining the largest percentage of energy savings per customer. *In 2016, funding for bill discounts in the deregulated areas of ERCOT ceased, and the amount spent per customer on low-income programs in these utilities plummeted.*

• In addition to bill subsidies and weatherization, Austin's utility has a rebate program for multifamily complexes, where many low- and moderate-income customers reside. Since 1990, the program has easily helped tens-of-thousands of tenants in the lower half of income.

Energy Efficiency Benchmarks at Texas Utilities 2014

Utility	Percent of Total Consumption Saved by Efficiency/Solar in 2014	Amount Spent on Low/Moderate Income Programs Per Customer
Austin Energy	1.11%	$32.85
CPS San Antonio	0.58%	$27.40
AEP Central*	0.26%	$26.08
AEP North*	0.21%	$25.80
Texas New Mexico Power*	0.21%	$27.80
Centerpoint*	0.18%	$27.74
Oncor*	0.18%	$27.38
* ERCOT in deregulated areas		

The failure to reach these low-participating sectors and end uses indicate that new approaches are needed. They involve education, outreach and targeted marketing, and most importantly, creative financing. Financing in particular is key to defraying the sting of first costs. A package that includes rebates, financing, and possible tax write-downs would help influence landlords.

The Bank of No Return

If the only thing Austin can do for low- and moderate-income consumers is throw money at problems to make ourselves feel less guilty, we will not be helping them much. We need to think strategically and choose carefully because there will never be enough money to provide all the assistance needed. The single-minded approach of low-income weatherization needs to be diversified to include other strategies that can save more energy and money.

A rich person will not invest in the Bank of No Return. Why should we treat the poor any differently?

Endnotes

1 Austin Energy, "Data Analysis on Impact of HVAC and Refrigerator Installs in AE Low Income Weatherization Program," January 9, 2015. Online at http://www.austintexas.gov/edims/document.cfm?id=224391

2 Example 1: Derived from footnote 1.
Example 2: Average 2014 discount of $252 in Austin Customer Assistance Program
Example 3: 2015 analysis assumes $10 per bulb, $25 professional installation, 9.5 bulbs per home, $38 in savings per year. (Since 2015, LED prices have fallen.)

3 Case Study: Seattle City Light's Powerful Neighborhoods Program, Spokane, WA: Ecova. Online at http://www.ecova.com/discover/case-study-seattle-city-lights-powerful-neighborhoods-program. Accesed 4/9/17

4 U.S. Census, American Community Census, Tenure by Household Income in the Past 12 Months (In 2015 Inflation Adjusted Dollars), Data, access 2/6/17.

5 U.S. Census, American Community Census, "Financial Characteristics," 2011-2015 American Community Survey 5-Year Estimates, Data, accessed 2/6/17.

6 Assumes a base level SEER of 7 to 8 for small central systems (18,000 BTUs) compared to most efficient system SEER of 15.

7 Assumes base level HSPF of 3.4 for electric resistance furnace for small central systems compared to 8.5 for most efficient heat pumps.

8 Assumes base level HVAC SEER of 7 or 8 for small central systems (18,000 BTUs) compared to 38 for most efficient mini-split air conditioners; assumes base level HSPF of 3.4 compared to 15 for mini-split heat pumps. Mini-splits are rated at lower BTU output, though central units in small apartments are almost all oversized.

9 Drehobl, Ariel and Lauren Ross, *Lifting the High Energy Burden in America's Largest Cities: How Energy Efficiency Can Improve Low Income and Underserved Communities*, Washington, D.C.: American Council for and Energy Efficient Economy, 2016, p.5. Data for 2013.

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11 Chart Data came from the following sources:

Texas Energy Efficiency Plans for 2014
Texas Public Utility Commission Online portal at http://interchange.puc.texas.gov/WebApp/Interchange/application/dbapps/filings/pgSearch_Results.asp?TXT_CNTR_NO=44480&TXT_ITEM_NO=19

CPS San Antonio Efficiency Plans and Other Data
"Three-Year Highlights, Unaudited," *2014/2015 CPS Energy Annual Report,* San Antonio, TX: CPS Energy, p. 19.
Frontier Associates, Evaluation, *Measurement, & Verification of CPS Energy's FY 2015 DSM Programs*, San Antonio, TX: CPS Energy, June 11, 2015.
FY 2015 Budgets for bill discounts, REAP, and Project Warm from Zandra Pluis, Deputy General Counsel, Legal Services, CPS Energy on December 4, 2015 and January 14, 2016.

Austin Energy
Customer Energy Solutions, *Program Progress Report 2014-2015, Appendix, Tables 1-5*.
Median Family Income for Travis County: U.S. Census, 2013 American Community Survey, "Income in the Past 12 Months (In Inflation Adjusted Dollars)," accessed 2015
U.S. Census, American Community Survey, "Tenure By Household Income in the Past 12 Months (In 2013 Inflation Adjusted Dollar)," Table B25118, accessed 2015.
69% of Tenants in 2013 were under Median Household Income in 2013
Number of AE Customers in 2014 from Austin Energy (439,343)
Amount of Money for Customer Assistance Program and Plus 1 Program from Austin Energy Public Information Request, September 1, 2015

Deregulated Area Bill Discount Charge Per Customer Derived By Formula:
EIA 861 for 2014 – ERCOT Consumption for Retail Market Providers X 65¢ Per Mwh ÷ ERCOT Customer Number for Retail Market Providers (232,001,710 Mwh X 65¢ ÷ 6,510,505 Customers)
Cost Per Customer X Number of Customers for each Deregulated utility