Keeping the Lights On While Transforming Electric Utilities

By Lena Hansen and Amory B. Lovins
Originally published in Solutions Journal 2010

Electric utilities operate now much as they did a century ago—but the environment in which they operate is changing dramatically. Now more than ever before, utilities whose regulators reward them in the traditional way for selling more electricity risk losing revenue as customers use their electricity more efficiently.

Climate change and energy security concerns, coupled with advances in disruptive technologies, may make conventional power-generating assets uncompetitive to build or even to run. Potential competitors armed with new technologies, new business models, and greater cultural agility are emerging in many sectors.

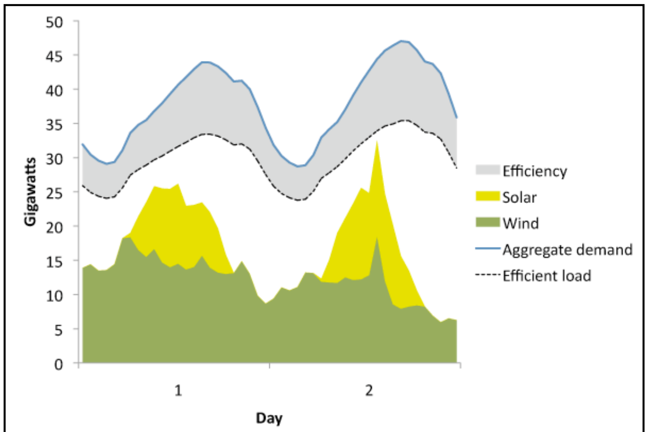
A New Electricity Paradigm

Responding to these disruptive forces requires a shift to a fundamentally new paradigm of electricity generation and use—business-as-usual incrementalism is simply insufficient.

The new paradigm will be based on a highly integrated network of advanced technologies including energy efficiency, demand response (which affects the timing rather than the efficiency of usage), renewables such as solar and wind, energy storage, and distributed generation.

Together, these technologies have the potential to make the electric system more secure, cleaner, and ultimately more cost-effective.

For this paradigm shift to succeed, though, it must meet both technical and economic requirements, delivering electricity reliably and cost-effectively throughout the transition.



Many renewable energy resources are available, but their output does not often match the profile of energy demand.

Unlike fuel, which can be easily stored, electricity must be generated at the instant it is needed and used at the instant it is generated. Electric utilities therefore provide highly reliable electric service by exactly matching electric supply with demand at every second of every day.

If this exact matching fails, the grid rapidly destabilizes, its components disconnect to prevent serious damage to the equipment, and the lights go out. Historically, utilities have met this exacting requirement by first measuring what they assumed was an uncontrollable demand, then tightly controlling their power plants' output to match the demand.

This approach is based on two underlying assumptions:

- Only supply, not demand, can be controlled by the utility.
- The portion of demand that is steady over time is best met by power plants that generate steadily (popularly called "baseload"), while other plants are cranked up and down to match the varying part of demand.

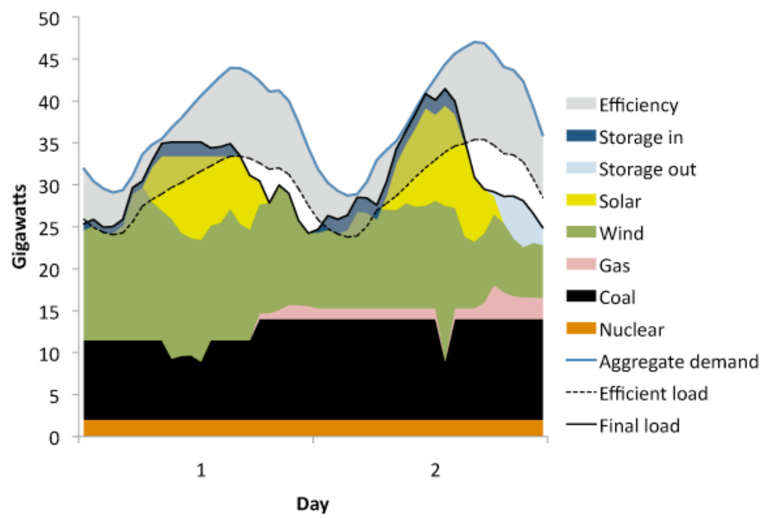
Putting Old Assumptions to Rest

These assumptions lead to a common concern that an electric system based on energy efficiency and renewables cannot provide reliable power. That's because utility operators cannot control when the wind blows and the sun shines, so these "variable renewable" resources cannot provide "baseload."*

That assertion is invalid—though the shift to efficiency and renewables will require operators to run their existing power plants and wires differently.

In reality, neither electricity demand nor generation is steady over time. Demand changes at every moment as individual devices turn on and off.

Individual customers' demands, therefore, are highly variable. The more customers, of more kinds, in more places, are aggregated, the smoother and more predictable the total demand on the utility becomes—but it will still vary substantially with time of day and over the year.



Energy storage and demand response technologies can increase load during times with excess renewable power, and decrease load during times when fewer resources are available.

The remaining demand is met by small quantities of natural gas-fired generation, along with output from electricity storage technologies (e.g. vehicles).

Similarly, no individual generator—from a huge, faraway coal plant to a small, rooftop solar array—has a completely steady output. All generators are intermittent—they sometimes fail without warning. They vary only in the size, duration, frequency, cause, and predictability of their outages. Even normally reliable big thermal plants have both planned and forced outages.

For example, North American Electric Reliability Council data for all U.S. generators during 2003–2007 show that coal-fired capacity was shut down an average of 12.3 percent of the time (4.2 percent without warning); nuclear, 10.6 percent (2.5 percent without warning); and gas-fired, 11.8 percent (2.8 percent without warning).

Despite extraordinary efforts to keep nuclear plants running constantly, the average unit worldwide unexpectedly failed to produce 6.4 percent of its energy output through 2008 and 5.3 percent in 2008, not counting planned refueling or maintenance shutdowns.

All this is to say that the concept of “baseload” generation is largely meaningless.*

For more than a century, utilities have known that any kind of power plant can and does fail, so they’ve routinely used controls and grids to combine intermittent generators to match fluctuating total demand.

People do not live on a desert island with one generator connected to one load; rather, the grid serves millions of individual loads by combining electricity from many power plants, of which at any given moment some are operating and others aren’t—either because they can’t or because they’re not needed.

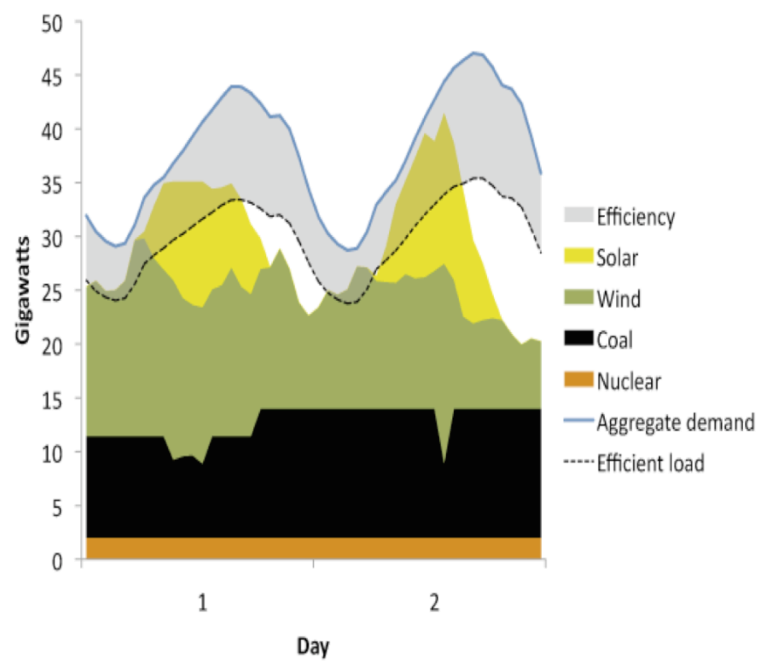
This is nothing new—utilities have been doing it since about 1882. All that’s new is that utilities, customers, and other market actors now have a much larger menu of technologies for producing, using, controlling, and communicating about electricity.

Smaller, Variable Resources Can Meet Demand

There is no technical or perhaps even economic reason why a set of smaller, more variable resources cannot reliably meet demand.

Since wind and photovoltaics produce electricity when the wind blows and the sun shines, whether or not that’s when the utility wants the electricity, the operator must simply control other resources (on the supply side or the demand side) to offset any differences so that total supply and demand continue to match up.

This is just like the conventional utility approach of managing one uncontrollable resource (historically, demand) with a set of controllable ones, but with two differences: demand can now often be controlled in ways that customers don’t notice or don’t mind (such as turning off an electric water heater for a few minutes), and modern forecasting



Existing coal and nuclear plants will play a smaller role. Coal plants are technically capable of changing their output to balance wind and solar variability.

Demand exceeds supply during some hours, meaning that enabling technologies will have to provide additional flexibility to the electric system to avoid curtailment or instability.

techniques often make renewable energy production from variable resources (windpower and photovoltaics) more predictable than demand.

The more diversified variable renewables are by location (so they experience different weather at the same time) and by type (so weather patterns that are bad for one are good for another), the steadier their total output becomes and the less capacity needed to produce that output.

Also, windpower and photovoltaics, the fastest-growing renewables, are the only two renewable generators whose variability is at issue. Half the world's electricity now made by renewables (other than big hydroelectric dams) is of other kinds—geothermal, small hydro, solar-thermal-electric with many hours of heat storage, biomass, and waste combustion, etc.—whose steady output utilities can "dispatch" just like thermal power plants.

Put simply, utilities must transition from operating a small portfolio of large power plants to more creatively operating a larger portfolio of small resources, while also incorporating additional flexibility from new advanced technologies.

A few ways in which utilities can successfully incorporate variable renewables include:

- **Using existing power plants differently.** Based on conventional economic dispatch (operating the cheapest-to-run plants most and the costliest-to-run plants least), utilities can adjust the output of existing power plants to manage supply and demand fluctuations. They simply use wind and solar generation to offset and reduce output from fossil-fueled plants—completely consistent with traditional utility logic, since renewable sources use no fuel and thus cost less to run.
- **Incorporating new technologies.** While the electric system has not changed much in a century, technology has. The likely rise of electric vehicles and advanced storage technologies can provide additional options to operators, storing surplus electricity in vehicle batteries and buying some of it back when and where it's most valuable, such as to meet peak loads downtown on hot afternoons.
- **Increasing control over demand.** The historical assumption that demand is uncontrollable is also changing as smart grid technologies allow consumers to have greater control over when they use electricity and to learn what it costs to provide at different times.

Some utilities already have extensive and successful experience with these approaches. For example, Denmark is already 20 percent windpowered, heading for 50 percent to 60 percent, and five German states are 30 percent to 40 percent windpowered (over 100 percent at some times).

In January, the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) released findings from its two-and-a half year **study** confirming that by 2024 the eastern U.S. could be over 30 percent windpowered with a "firming and integration" cost—the added cost of coordinating windpower with other resources to ensure reliable and cost-effective service—equivalent to just one-tenth of windpower's competitive average price today.

RMI's Reinventing Fire™ effort is figuring out how energy efficiency and renewables can be combined to take advantage of all the newest intelligent controls, smart grids, and new technologies—while keeping the lights on reliably and cost-effectively.

Then utilities can provide better service at lower cost; they and their customers can both make more money at less risk; grid vulnerabilities and power-plant emissions will decline; and innovation and entrepreneurship can flourish.
Not only is this possible, but it is critical to our energy, security, and environmental future.

---

*"Baseload" remains a valid and useful technical term that utilities apply to generating assets, but its definition is economic, not physical. A utility buying resources thinks of "baseload" as the new resource that will provide the cheapest electrical services over time. Once resources have been bought,
however, the utility operator's "baseload" resource is whichever resource costs the least to run (no matter what it cost to build), so that resource will be run whenever it is available and needed. These economic definitions say nothing about size, technology, or even whether the resource produces or saves electricity. Traditionally, big thermal (or hydro) power plants have been the default choice under both definitions of "baseload," but nowadays, new competitors—efficiency, many renewables, cogeneration—typically cost less to buy and to run, so big thermal plants now provide a minority and shrinking share of the world's new electricity production.

Lena Hansen is a Principal at Rocky Mountain Institute and Amory B. Lovins is the Cofounder, Chairman, and Chief Scientist.