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Rooftop solar and home batteries make a clean grid vastly more affordable

Distributed energy is not an alternative to big power plants, but a complement.

May 28, 2021

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Energy nerds love arguing over the value of distributed energy resources (DERs), the rooftop solar panels and customer-owned batteries that are growing more popular by the day. There's a [fight in California right now](#) over the value of energy from rooftop solar, just the latest skirmish in a long war that has [ranged over numerous states](#).

The conventional wisdom in wonk circles is that the value provided by DERs is not sufficient to overcome the fact that the energy they produce is, on a per-kWh basis, much more expensive than that produced by utility-scale solar, wind, and batteries (residential solar is roughly 2.5 times as expensive as utility-scale solar, [according to NREL](#)).

For that reason, many wonks view DERs as a kind of boutique energy and argue that public funds are better spent on utility-scale energy.

Turns out: no, that's wrong. Some groundbreaking new modeling demonstrates that the value of DERs to the overall electricity system is far greater than has typically been appreciated.

The work didn't get the attention it deserved when it came out in late December, so I want to spend some time with it. First, though, let's get clear on what we're talking about.

The misguided battle between centralized and distributed energy

To understand the difference between centralized and distributed energy, it's important to understand the distinction between transmission grids, the high-voltage power lines that carry electricity over longer distances, and distribution grids, the nests of low-voltage power lines (strung from the familiar brown poles) that carry electricity to local consumers. If the transmission grid is the interstate highway system of electricity, distribution grids are the local road systems that branch off those main trunks.

Centralized energy generally refers to utility-scale power generators (or energy storage) hooked up directly to the transmission grid: coal or natural gas plants, wind farms, solar fields, grid-scale battery stacks, what have you. The big stuff.

Distributed energy consists of anything that generates, stores, or manages electricity on distribution grids: rooftop solar panels, ground-mounted "community solar" arrays, consumer batteries, electric vehicles, building energy management software, and the like. (And then there's truly distributed energy, in the form of off-grid installations that don't connect to any larger grid. We won't be getting into that today.)



Some distributed solar covering a parking lot. (Photo: Getty Images)

To paint in broad and somewhat crude strokes, advocates for centralized renewable energy tend to view advocates for distributed energy as crunchy pastoral proto-hippies who can't handle modernity. They note that utility-scale energy is cheaper and capable of powering highly energy-dense modern economies, whereas distributed energy is expensive and diffuse.

Advocates for distributed energy tend to view advocates for centralized energy as corporate capitalists in thrall to perpetual growth. They note that distributed energy brings a range of benefits, from resilience and independence to savings on avoided infrastructure, whereas utility-scale energy tends to do greater damage to landscapes and concentrate economic power.

Like many disputes in the energy world, this one has hardened into an identity battle, which is annoying and unproductive, since the answer, like with so many other disputes, is *both-and*.

Nonetheless, it's worth noting that advocates for distributed energy have been at something of a disadvantage to date. It can be devilishly difficult to quantify the benefits of DERs, so a lot of the discussion gets into hand-wavy intangibles.

It can be especially difficult to quantify the benefits of DERs to larger grid systems, because energy modeling to date has effectively ignored distribution grids (which represent about a third of US spending on electricity). It has treated them purely as load, as demand to be satisfied, rather than as active, flexible participants in grid management.

Until now!

Or, until a few months ago anyway. In December, energy modeler Christopher Clack (a [familiar name](#) to Volts readers) and his team at Vibrant Clean Energy (VCE) debuted a new way to model the energy system that takes into account DERs and the services they provide. They used it to study the effect of DERs on the electricity system and the results are summarized in "[A New Roadmap for the Lowest Cost Grid](#)." (Full technical report [here](#); slideshow presentation [here](#).)

Spoiler: the cheapest possible carbon-free US grid involves vastly more centralized renewable energy, but it also involves vastly more distributed energy. What's more, far from being alternatives, they are complements: the more DERs you put in place, the more centralized renewables you can put on the system. DERs are a utility-scale renewable accelerant.

The practical implication is that going all out on DERs is to everyone's benefit, up and down the electricity supply chain, from utilities to consumers.

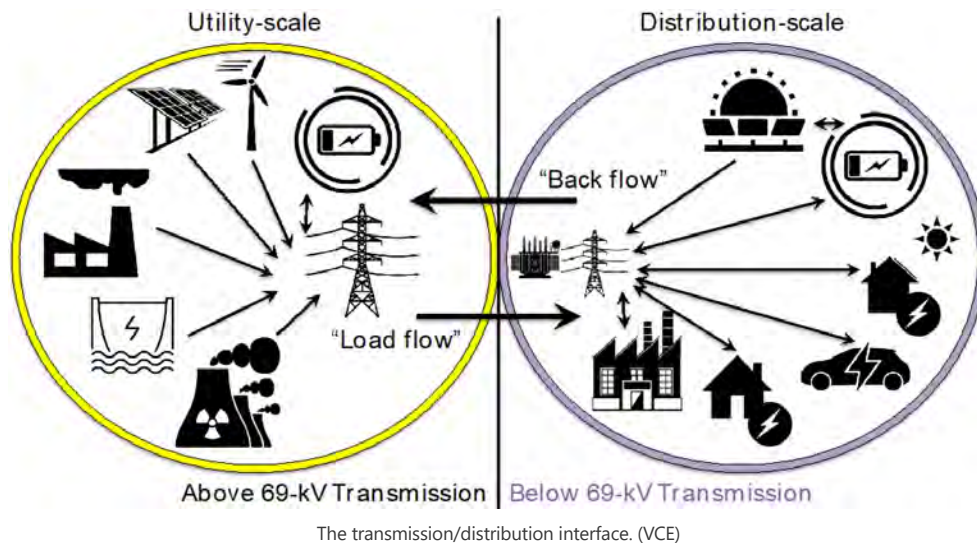
It is difficult to exaggerate just what a revolutionary change this represents in energy modeling and how much it turns conventional wisdom on its head. By making distribution grids visible to their model and co-optimizing those grids with the transmission system, the team at VCE uncovered a source of grid flexibility that could save a decarbonizing electricity system some half a trillion dollars through 2050. That's real money.

(If you want to take a deep dive into the material, check out [this interview with Clack on Chris Nelder's Energy Transition Show](#). It is gleefully nerdy; I cannot recommend it highly enough.)

The cheapest energy scenario is clean and distributed

At the heart of VCE's work is Clack's state-of-the-art modeling tool: [Weather-Informed energy Systems: for design, operations and markets planning \(WIS:dom\)](#). It allows resolution down to two-mile square areas and makes dispatch decisions every five minutes. It takes into account granular weather data stretching over decades, climate impacts, policy, all forms of generation, storage, transmission, and on and on. VCE boasts that it "leverages 10,000 times more data points than traditional models."

For this study, WIS:dom was augmented to better understand and represent distribution grids, so that it could bring transmission and distribution systems together in one system and co-optimize them. It was given better information about the costs and capabilities of DERs and more options; for example, instead of spinning up a new generator to meet peak demand, it could draw on distributed solar and batteries.



No one to Clack's knowledge has done this before, so there was a lot of experimenting to get it right. "I had to spend a lot of money and time and resources upgrading the model to include this, with a lot of failures along the way," says Clack. "That's why I'm confident that we did it first, because I spent a lot of time trying to find someone else that had done it, so I didn't have to do the hard work."

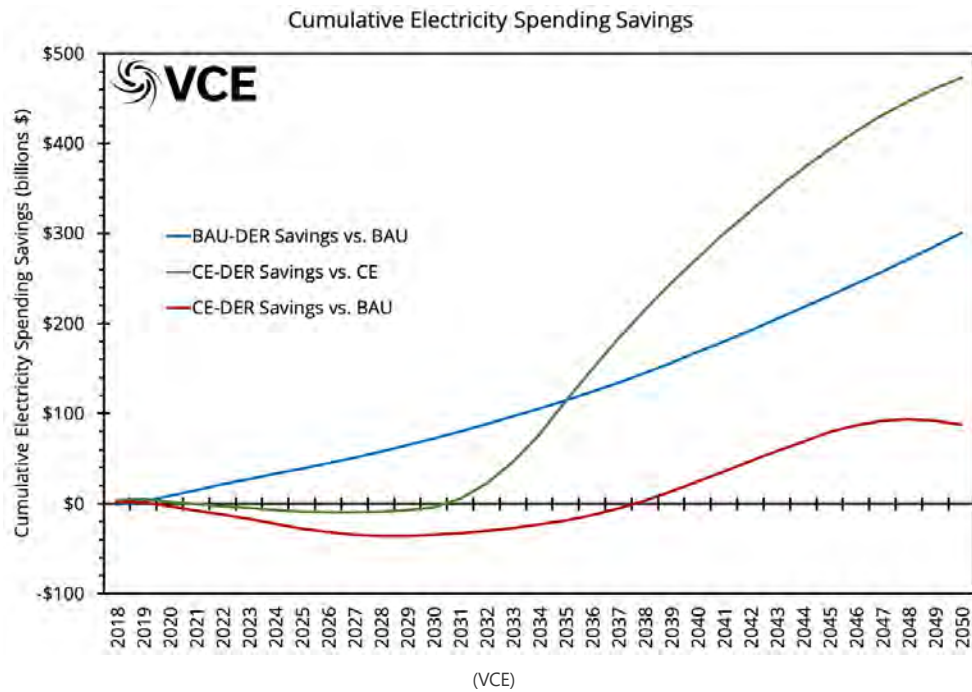
The modeling question was: if a high-resolution optimization tool is given DERs as an option, will it choose to deploy them? If so, how much?

The broader social question was: can DERs help lower the overall costs of a clean electricity system? If so, by how much?

The paper presents four core scenarios (which were run across a range of geographies):

- **BAU** (business as usual), which includes existing policies and mandates but otherwise lets economics drive dispatch decisions; it deploys WIS:dom in a way that mimics traditional models;
- **BAU-DER**, which does the same but uses the augmented form of WIS:dom, with greater visibility into distribution systems;
- **CE** (clean energy), which models a system that reduces power sector carbon emissions 95 percent from 1990 levels by 2050; WIS:dom mimics traditional models;
- **CE-DER**, which models a 95 percent reduction but uses the augmented form of WIS:dom.

To skip straight to the results: if you make DERs an option for the model, it deploys an absolute boatload of them (spending about \$10 billion extra over the first 10 years), and by doing so substantially reduces overall system costs.



BAU-DER is \$301 billion cheaper than BAU (the blue line above), which means we would save money from day one by deploying more DERs even if we didn't care about climate change.

CE-DER is \$473 billion cheaper than CE (the green line), which means DERs will make the decarbonization of electricity much less expensive than doing it all with centralized renewables and storage.

And here's the kicker: CE-DER is \$88 billion cheaper than BAU (the red line), which means, economically speaking, we'd be better off reducing electricity emissions by 95 percent using DERs than continuing with the status quo.

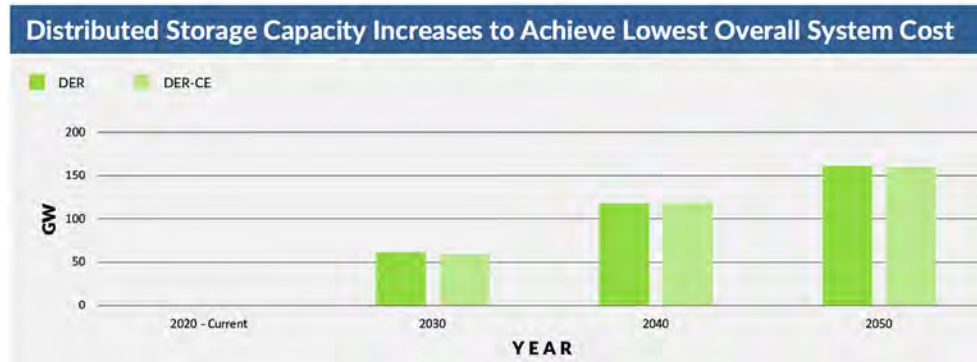
(And this is all just the pure economics — it leaves out the enormous health savings and environmental justice benefits of reduced point-source pollution.)

Whether you're concerned about climate change or not, whether you want to reduce emissions or not, whether you care about the health and resilience of local communities or not, deploying DERs brings down system costs. It's the fiscally responsible thing to do.

Now, note the shape of the red line above (and to a lesser extent, the green line). Scenarios that decarbonize using DERs are a smidgen more expensive for the first 10 years or so because they use those early years to deploy an enormous quantity of DERs.

The US currently has about [98 gigawatts of rooftop solar](#) and less than a gigawatt of distributed energy storage installed. Through 2025, CE-DER deploys an additional 75 gigawatts of distributed solar and 27 gigawatts of distributed storage; by 2035, it is 200 and 90, respectively. (By 2050, it is 247 and 160.)

That is an absolute DER building binge, starting now.



(VCE)

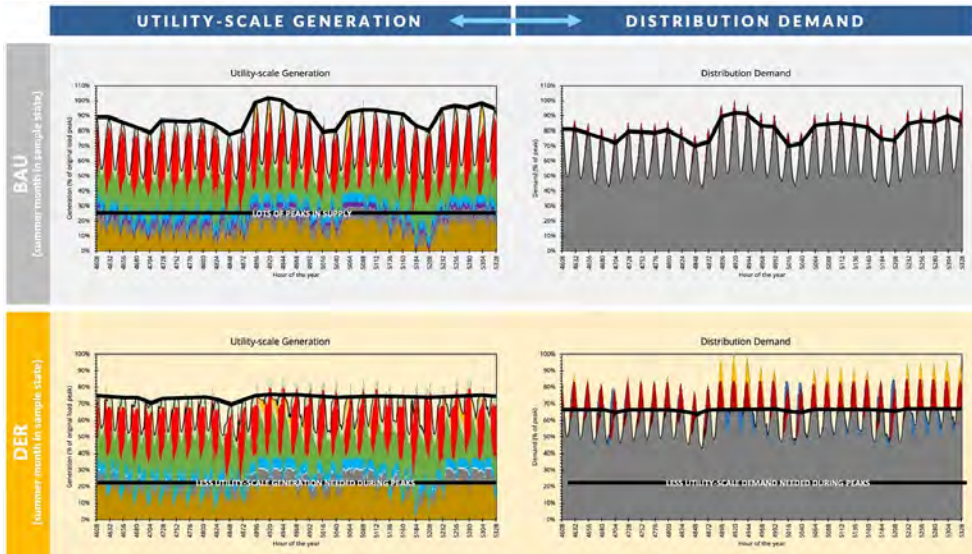
After that early period of heightened investment, though, savings begin to skyrocket as DERs pay off in system benefits.

DERs make everything else on the grid work better

For the entire history of electricity up until about five minutes ago, grid operators viewed electricity demand as an exogenous variable, a set figure they had to meet with supply, not something they had much control over.

The key to the value of DERs is that they make electricity demand more controllable. With energy generation and storage scattered throughout distribution grids, grid operators have a way to move energy around, both geographically and temporally, without firing up more power plants. They can absorb extra energy if there's a dip in demand or produce extra energy if there's a spike. The overall effect is to smooth out the "demand curve."

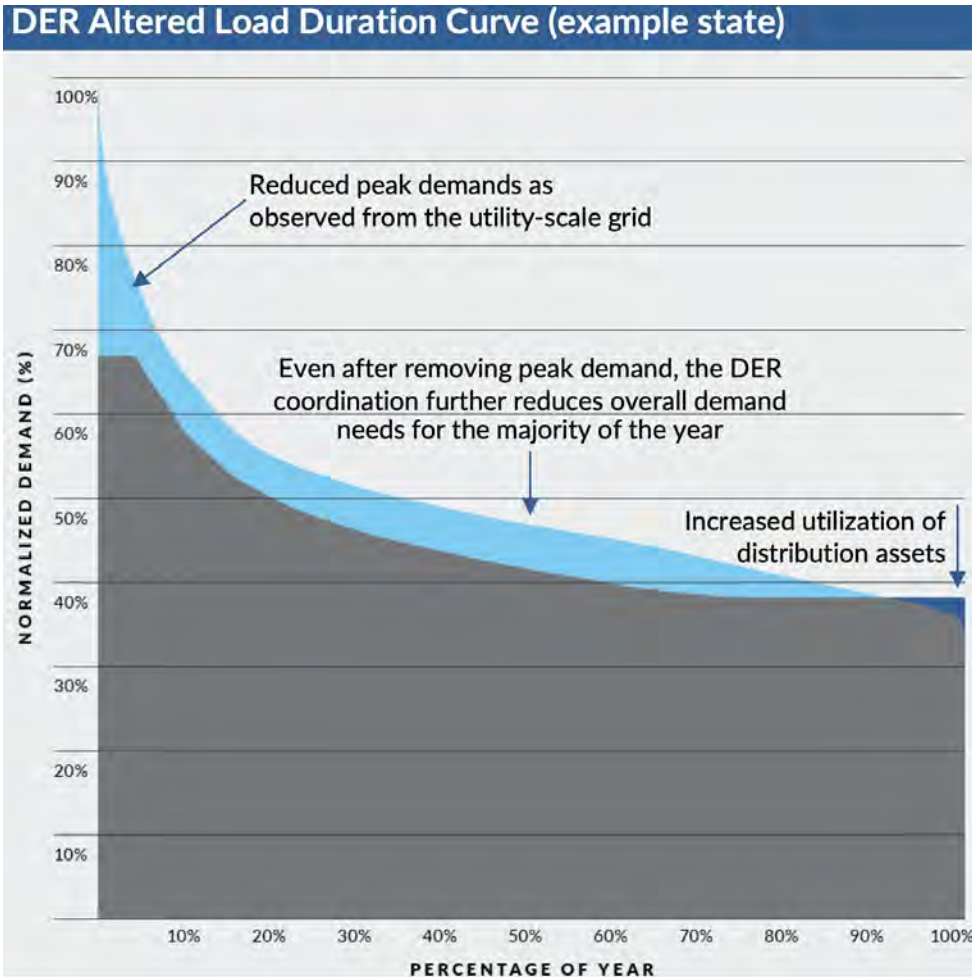
Look at the thick black line on the top right graph below — that's the distribution demand curve throughout a representative year:



Look at the demand curve on the top right and then on the bottom right: flatter! (VCE)

Now note the same black line on the bottom right graph. By satisfying the little demand peaks with distributed solar and storage, the demand for utility-scale energy is leveled off.

Here's a graph that shows a "load duration curve," which reveals how high demand is, for how often in the year, and how DERs affect it:



(VCE)

As you can see by the sharp spike on the left, there are relatively rare periods of extremely high demand (peaks). The problem is that the current electricity system has to be sized to meet those peaks, even if that means many power plants end up idle most of the time. Clack says that today, roughly 20 to 25 percent of generation capacity on the grid — some 300-350 gigawatts — covers around 3 percent of the energy load each year. (This, in a nutshell, is why electricity systems everywhere are so overbuilt.)

The light blue-shaded area on the curve shows the reduction in demand that DERs can provide (the dark blue on the right is the increase in demand). Not only can DERs “shave the peak” by an average of 17 percent nationwide, they can reduce the demand for utility-scale energy for 80 percent of the hours of the year. They make the load duration curve more level as well.

These demand-leveling effects bring four big benefits:

- First, if you don’t have those big peaks in demand for utility-scale energy, then you don’t need that 20 to 25 percent of capacity that only runs during peaks. Not building those plants, or shutting them down early, saves lots of money.
- Second, a more level demand curve means that all generators on the system will run more consistently, with fewer ramps up and down, at closer to their full capacity, helping to maximize their value.
- Third, a more level demand curve means that transmission congestion will be reduced and transmission assets will be more efficiently utilized. (In [one of my Transmission Month posts](#), I discussed “energy storage as a transmission asset.” This is the same idea, on a broader scale.)
- Fourth, DERs offer the system the option to shift demand to meet variable supply, rather than always forcing it to shift supply to meet demand. Shifting demand is often *much* cheaper.

These benefits explain why CE-DER is so much cheaper than CE, and even than BAU. They explain why, even though rooftop solar may cost more than centralized solar on a per-kWh basis, its value is greater.

Infusing distribution systems with DERs allows grid operators more stability and more options — including more renewables.

DERs enable more utility-scale renewables

Wind and solar are cheap, but they are variable. They come and go on their own schedule, outside of our control. There will be times — seconds, minutes, hours, sometimes weeks and months — when wind and solar dip and something else is needed to fill the gaps.

Conventionally, this role is played by dispatchable generators that can be turned up and down at will — these days, mostly natural gas plants. Given that most natural gas plants, at least those without carbon capture, will have to be phased out in a decarbonized system, there’s a hunt on for “firm” zero-carbon alternatives — think nuclear, hydro, natural gas or biomass with carbon capture, or geothermal.

But VCE’s modeling shows that a big chunk of that role can be played by DERs, which Clack calls a “firming agent on the load.”

By bringing demand more under grid operators' control, DERs virtually eliminate curtailment, or discarding of renewable energy due to temporary oversupply, through 2045. Just as they allow transmission to be used more effectively, they allow us to consume more of the energy generated by existing utility-scale renewables.

They also prevent the familiar problem of "value deflation" — more wind and solar energy at particular times and places competes with existing wind and solar energy from the same times and places — by giving grid operators a whole series of time- and location-specific demand knobs that they can turn up or down at will to better accommodate renewables.

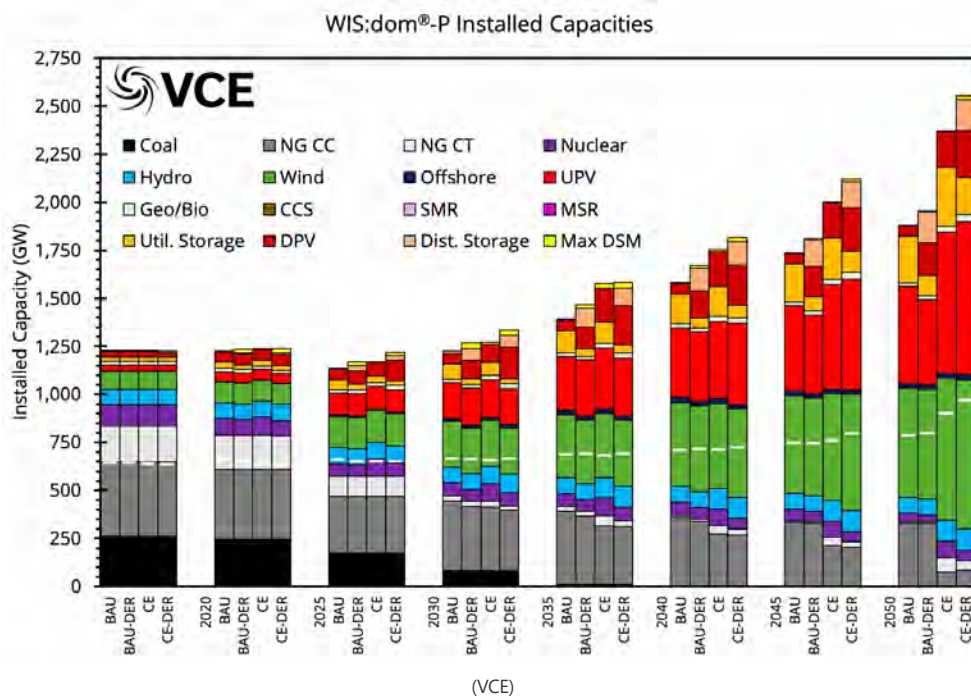
By preventing value deflation, DERs will allow for more new renewables on the system (and the retirement of more thermal and fossil generation). That's why the CE-DER scenario builds *more* utility-scale wind and solar than the CE scenario. CE-DER builds 800 gigawatts of utility wind, 800 of utility solar, and 200 of utility storage, whereas CE builds 60 gigawatts less wind and 50 less solar (though slightly more batteries).

By enabling renewable energy to be moved around, DERs unlock more of it — with, again, enormous public health benefits that are not captured in the model.

Put technically, as Clack told Nelder, "the model says that distributed [solar] and storage in some combination ends up being higher value than the differential in the [levelized] cost of utility-scale solar and distributed solar."

Put more colloquially, though it will require enormous upfront investment in the coming decade, laying a quilt of DERs over the nation's distribution systems is the best thing we can possibly do to enable the rapid emission reductions we will need in the decade after.

DERs are not a boutique version of, or a distraction from, utility-scale renewables; they are a necessary complement, an enabler and accelerator.



DERs will mean more jobs

VCE did some analysis estimating that the DER-enhanced scenarios would add an additional million jobs per year relative to conventional scenarios.

It stands to reason that a huge deployment of DERs would create lots of jobs. These are very hands-on, labor-intensive projects. And since distribution systems are ubiquitous in the US, it would create jobs in every part of the country (though not uniformly).

I'm generally suspicious of employment projections, so I don't know how much stake to put in the particular figure, but we can be confident that more DERs = more jobs.

DERs could hasten the collapse of existing power markets

VCE's modeling shows that current electricity markets, if they are not reformed, basically collapse in the next 10 to 20 years. DERs will hasten that collapse in two ways.

First, they will reduce demand peaks, which produce a great deal of value in current markets. Lots of peaker plants will get cancelled or shut down and peaker money will dry up.

Second, DERs will enable more utility-scale wind and solar, which have zero marginal costs. They are all upfront capital costs; once a solar panel is in place, it doesn't cost it anything more to produce the next kW. It can bid into markets at \$0. Pretty soon, so much of the market's power will come from zero-marginal-cost sources that prices will be \$0 most of the year, and \$0 means zero profit for participating generators.

Electricity markets were built for fossil fuel generators. They need reform — but that's a topic for a different post. ([This](#) is a good start.)

Clean electrification boosts the value of DERs

An intriguing note: Clack says that if WIS:dom is told not just to decarbonize electricity but to decarbonize the whole economy (i.e., [electrify everything](#)), the value of DERs to the grid effectively doubles.

An economy-wide decarbonization scenario that makes use of DERs saves a *trillion dollars* relative to one that doesn't. VCE will have a new report on economy-wide decarbonization coming out soon.

DERs also provide a range of co-benefits

VCE's modeling only captures DERs' contribution to overall grid performance and cost. It does not capture many of the benefits that have long attracted customers to them: resilience against brownouts and blackouts, the capacity to go off-grid temporarily (or permanently), independence from the whims of utilities and state regulators, reduced personal greenhouse gas emissions, and most of all, lower electricity bills.


All of those benefits will help drive early adoption of DERs as their value to the grid ramps up (though they should be boosted by utility, state, and federal incentives).



The value of DERs should be visible in all models and states

Clack says that it's just four paragraphs of code that open WIS:dom up to distribution grids — other models, including the models that utilities use in planning, could easily replicate this.

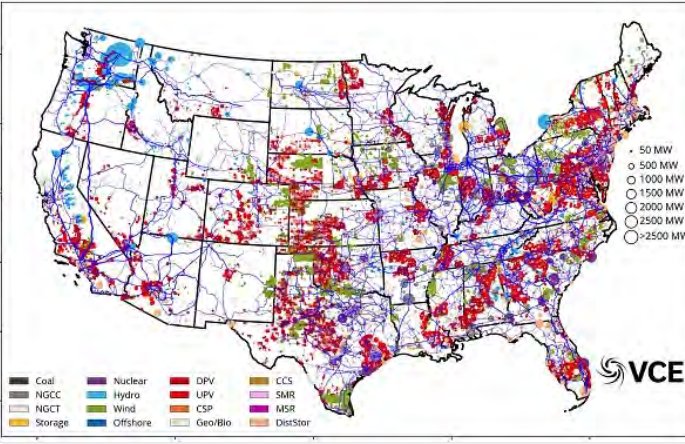
"One of the reasons I was so keen on having it be relatively simplistic is, it should be able to be adopted by other models," he says. "Maybe they wouldn't show as much savings as we do,

because of different model logic, but I'm pretty confident they will show similar trajectories."

 Vibrant Clean Energy
@VibrantCE

 FULL TECHNICAL REPORT RELEASED 

Today, we have released our full technical report on the "Why Local Solar and Storage Costs Less". Two weeks ago, we released the main findings: savings of \$473 billion when co-optimizing distribution. This released provides more details!



7:06 PM · Dec 14, 2020

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This is just one more area where outdated utility models and practices are keeping costs too high and the clean-energy transition too slow. Utilities have traditionally been hostile to DERs, viewing them as competitors or net costs, but VCE's modeling demonstrates what should have been obvious: having flexible generation and storage infused throughout distribution grids offers a fantastic tool to help stabilize a grid with growing renewables and increasing electric loads and bring costs down for all ratepayers.

VCE's work is obviously germane to the many fights going on across the country over net metering. (See [California in particular](#).) Utilities want to pay solar homeowners less for the energy they produce, but VCE's modeling shows that, if anything, they should be paid *more*. They can help reduce rates for all ratepayers. It makes fiscal sense for utilities and states to incentivize as much DER growth as humanly possible.

Utilities need to stop viewing DERs as an intrusion, a disruption, or a distraction. They are not simply smaller, more expensive versions of utility-scale energy. They are a firming foundation that will help utilities build stable, reliable decarbonized electricity systems.

DERs are good for everyone

It's not often you come across an energy solution that's truly win-win, but DERs, if they are properly understood and deployed, are good for just about everyone.

They save building owners money, increase individual and community resilience, create local jobs, reduce peak demand, level the demand curve, get more out of existing power generators and transmission lines, unlock more utility-scale wind and solar, boost reliability, and reduce system costs.

We should build lots of them, everywhere, starting now.

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