Vox

A beginner's guide to the debate over 100% renewable energy

Is it the right target? Is it even possible?

Updated by David Roberts | @drvox | david@vox.com | Apr 4, 2017, 10:20am EDT

Enough? | (Shutterstock)

Imagine powering civilization entirely with energy from renewable sources: wind, sun, water (hydroelectricity), naturally occurring heat (geothermal), and plants.

No coal mines, oil wells, pipelines, or coal trains. No greenhouse gas emissions, car exhaust, or polluted streams. No wars over oil, dependence on foreign suppliers, or resource shortages.

Sounds nice, right?

A growing number of activists say it is within reach. The idea has inspired ambitious commitments from an **increasing number of cities**, including Madison, Wisconsin, San Diego, and Salt Lake City. Advocates are **pushing states** to support the goal.

Clean-energy enthusiasts frequently **claim** that we can go bigger, that it's possible for the whole world to run on renewables — we merely lack the "**political will**."

So, is it true? Do we know how get to an all-renewables system?

Not yet. Not really. Current modeling strongly suggests that we will need a broader portfolio of low-carbon options, including nuclear and possibly coal or natural gas with carbon capture and sequestration (CCS), to get deep cuts in carbon.

However, that's only current modeling. There are many reasons to question what models tell us about the future three, four, five decades out. They have typically underestimated renewables and likely still are. There is much debate, not only about what models show, but what lessons we should take from them and how we should approach the task of decarbonization.

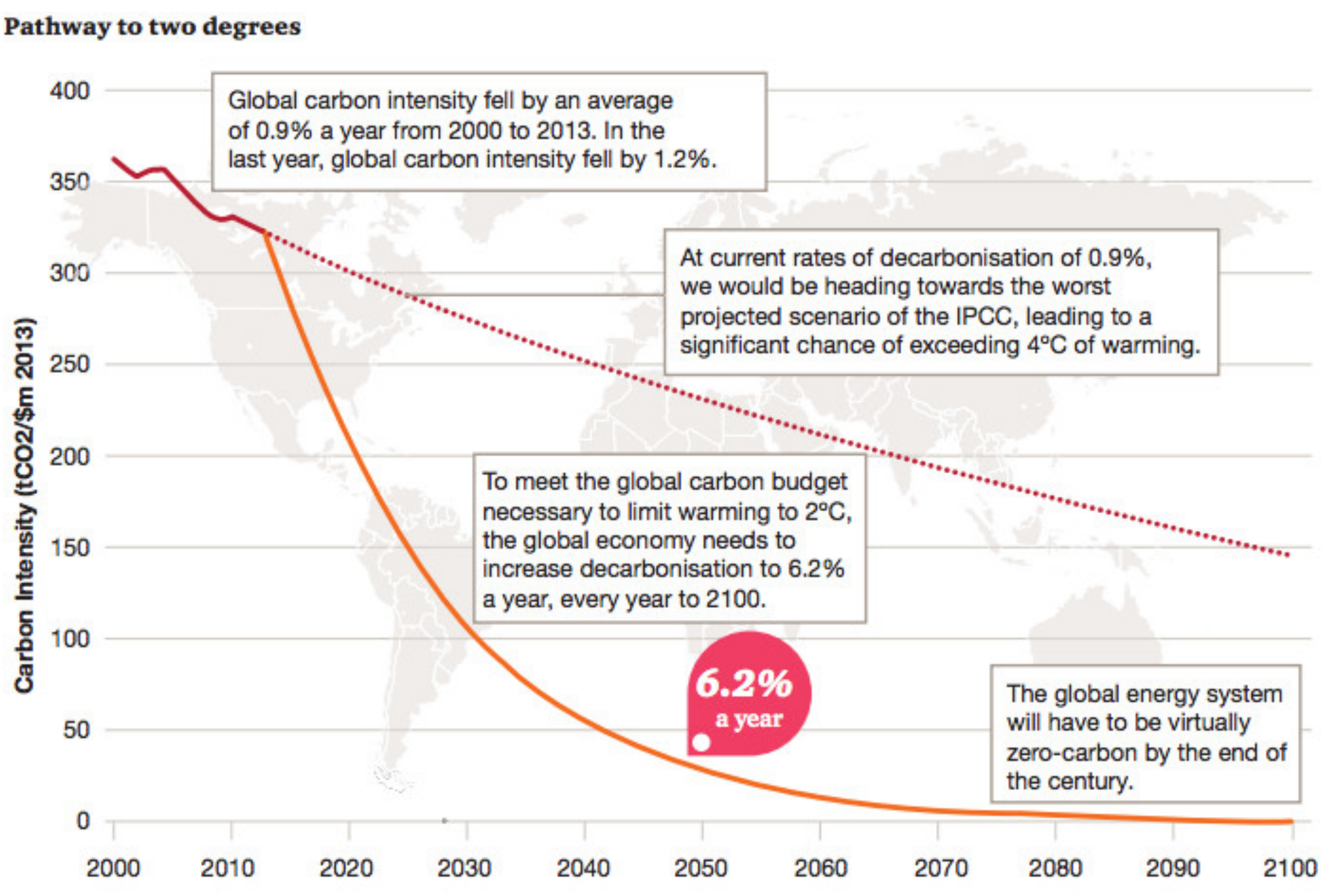
But all that is a bit in the weeds. Before we get into the nerdy back and forth — as I will in a subsequent post — let's take a step back.

In this post, I simply want to introduce the debate over 100 percent renewable energy to those who aren't familiar with it. Consider this a basic lay of the land, to get you oriented.

It's not about whether to go to zero carbon, but how to get there

The most important political division in the world of climate change is between those who accept the urgency of the problem and those who don't. Those who don't are **in charge of the federal government** these days. Their energy plans are a celebration of fossil fuels.

The debate over 100 percent renewable energy isn't about that division. This is about a dispute among people who accept the imperative to rapidly reduce carbon emissions, sufficient to hold the rise in global average temperatures to less than **2 degrees Celsius** (3.6 degrees Fahrenheit) over preindustrial levels. To hit that globally agreed upon target requires "deep decarbonization" — reducing total carbon emissions 80 to 100 percent — across the globe, by mid-century or shortly thereafter.



Looks tough. | (PriceWaterhouseCoopers)

Both sides in this dispute agree that any deep decarbonization scenario is going to crucially involve **electrifying everything**. Specifically, it will involve doing two things at once: a) eliminating carbon emissions from the electricity sector and b) moving as many other energy services as possible (transportation, heating, and industry) over to electricity.

(Yes, I'm aware "everything" is an exaggeration — there will likely always be tasks that require liquid fuel combustion — but it is, as my grandfather used to say, close enough for government work.)

Doing that — using electricity to get around, heat our buildings, and run our factories — will increase demand for power. Different models predict different things, but at the high end we're talking about power demand growing by 150 percent or more through mid-century.

That means the electricity grid will have to get bigger, more sophisticated, more efficient, and more reliable — *while it is decarbonizing*. That is the central challenge of deep decarbonization.

So what's the best way to get there?

That's where the dispute comes in. On one side are those who say we should transition to an electricity system powered entirely by renewables, most notably the **Solutions Project**, based on the work of **Stanford's Mark Jacobson**, backed by a board of high-profile greens including Van Jones, Mark Ruffalo, and Jacobson himself.

On the other side are those who say that the primary goal should be zero carbon, not 100 percent renewables. They say that, in addition to wind, solar, and the rest of the technologies beloved by climate hawks, we're also going to need a substantial amount of nuclear power and fossil fuel power with CCS.

That's the dispute. Some climate hawks oppose nuclear and CCS. Others — with attitudes varying from enthusiasm to weary resignation — believe that they will be necessary for deep decarbonization.

(If you shrug and say, “it’s too early to know,” you’re correct, but you’re no fun to dispute with.)

The heart of the renewables challenge: compensating for variability

The entire dispute revolves around a simple fact: The most abundant sources of carbon-free power, wind and sun, are variable. The sun is not always shining; the wind is not always blowing.

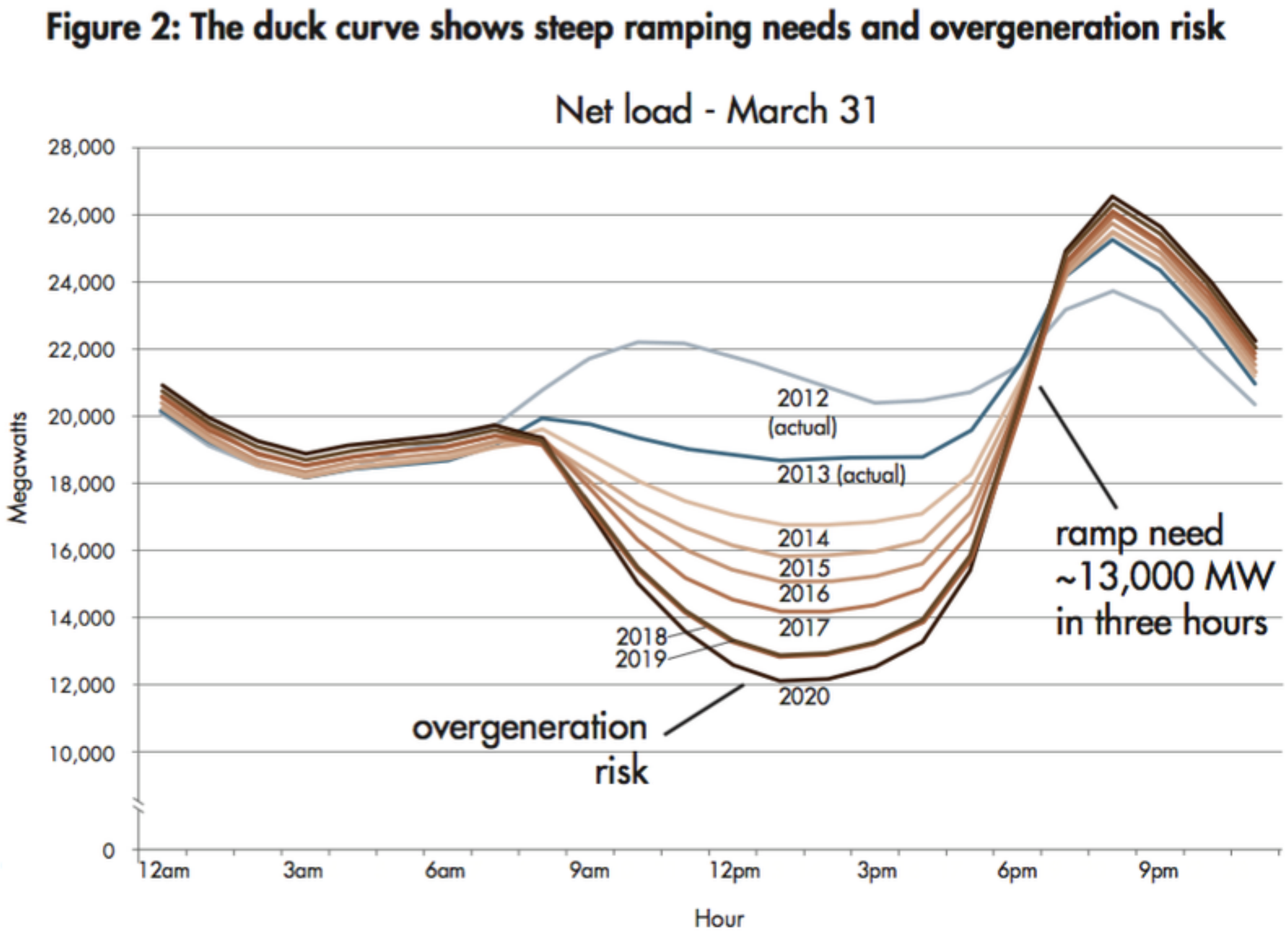
The fact that they are variable means that they are not *dispatchable* — the folks operating the power grid cannot turn them on and off as needed. The power comes when it comes and doesn’t when it doesn’t. Grid operators adjust to them, not the other way around.

As more and more of a grid’s power comes from variable renewable energy (VRE), two sorts of problems start to arise.

One set of problems is technical (explained in more detail **here**). As VRE capacity increases, grid operators increasingly have to deal with large spikes in power (say, on a sunny, windy day), sometimes well above 100 percent of demand. If there’s no way to absorb that surplus energy, it is “**curtailed**,” i.e., wasted.

They also have to deal with large dips in VRE. It happens every day when the sun sets, but variations in VRE supply can also take place over weekly, monthly, seasonal, and even decadal time frames.

And finally, grid operators have to deal with rapid ramps, i.e., VRE going from producing almost no energy to producing a ton, or vice versa, over a short period of time. That requires rapid, flexible short-term resources that can ramp up or down in response.



The much-discussed (among electricity nerds) "duck curve" — demand for utility power over one day in CA as VRE increases. | (CAISO)

That's the technical challenge. There's also an economic problem (explained in more detail **here**).

As each new megawatt (MW) of VRE comes online, it incrementally reduces the value to the grid of the *next* MW of VRE. A new MW of wind capacity is only going to generate energy when the other wind capacity is generating energy. Same with solar.

As more and more wind and solar come on the grid, the value of resources that can provide energy when VRE *isn't* generating will rise; correspondingly, the marginal value of the next unit of VRE will decline. That means solar, especially, has to clear a **higher**

and higher economic bar.

Now, to be clear: There are **tools to address these technical and economic problems**. Lots of tools, more every day. There's a whole blooming, buzzing swarm of research and innovation happening in this area. (More on that **here**.)

The dispute comes down to whether these problems can be solved without nuclear and CCS.

The last 10 to 20 percent of decarbonization is the hardest

It is possible to get substantial decarbonization using well-understood technologies and policies.

A great deal can be accomplished just by substituting natural gas combined cycle power plants for coal plants. While that's going on, you grow renewables and maintain your existing nuclear and hydroelectric fleet. That is, practically speaking, how the US has reduced carbon emissions in recent years.

The strategy works great for a while. Natural gas plants are much more flexible than coal plants, so they work as a nice complement to VRE, balancing out variability.

But in terms of deep decarbonization, the strategy eventually leads to a cul de sac. Natural gas is cleaner than coal (by roughly half, depending on how you measure methane leakage), but it's still a fossil fuel. At least without CCS, it is incompatible with decarbonization beyond 60 percent or so.

If you build out a bunch of natural gas plants to get *to* 60 percent, then you're stuck shutting them down to get *past* 60 percent.

It would be very difficult to strand all those assets. There would be a *lot* of resistance. It's just one example of path dependence in energy — choices, once made, tend to perpetuate themselves through inertia. Leaning too heavily into natural gas in the next 20 years will make it more difficult to pull away in the subsequent 20.

Natural gas, you sweet, sweet siren. | (Shutterstock)

Avoiding that cul de sac means thinking, beginning now, about how to replace all that natural gas with other balancing resources that don't emit carbon.

The balancing act to achieve carbon-free electricity

Think of a carbon-free grid as a balance of two kinds of electricity resources, dispatchable and non-dispatchable.

As we noted earlier, non-dispatchable means VRE — on and offshore wind, solar PV, solar thermal, run-of-river hydro, anything based on weather — that can't be turned on and off.

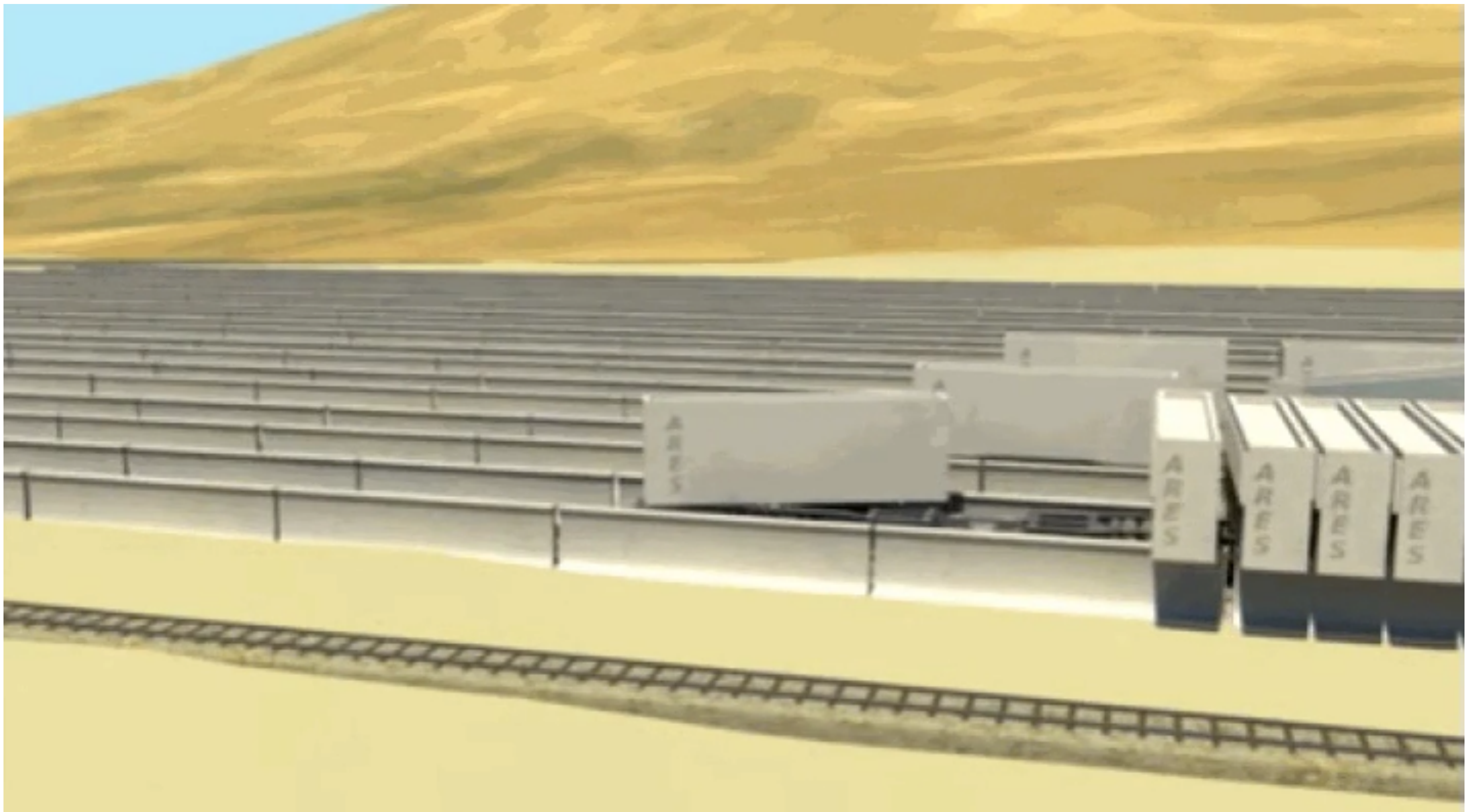
VRE can be made somewhat less variable by linking up resources over a wide geographical area with more transmission lines. Over a large enough area, it's usually sunny or windy somewhere. But in a constrained grid, non-dispatchable resources generally need balancing out with dispatchable resources.

Dispatchable is a broad (and getting broader) category — it means anything that grid operators can use to actively manage the balance of electricity supply and demand.

There are three basic varieties:

- **Dispatchable supply**, i.e., power plants — in the low-to-no carbon family, this includes nuclear (by far the most common, generating **11 percent** of the world's electricity as of 2012), fossil fuels with CCS, reservoir hydro, biomass (though it is controversial), and geothermal.
- **Dispatchable demand** — increasingly, demand for power can be managed, either reduced or shifted to different parts of the day/week.
- **Energy storage** — storage is interesting because, from a grid operator's perspective, it can serve either as dispatchable demand (absorbing surplus VRE) *or* dispatchable supply (releasing energy during times of low VRE). And there are a growing number of ways to store energy. The oldest and highest capacity is **pumped hydro**, whereby water is pumped uphill to store energy and then run down through turbines to release it. (A company in the American West is attempting a dry-land variation of this, **pushing giant blocks uphill on train tracks**.) There are also batteries, which are getting cheaper. And beyond that power can be stored as heat (in, e.g., molten salt), as cold (in ice), or as hydrogen (long story). This is also an area of furious research.

Among these three categories, resources range from high capacity (enough power to cover demand for weeks or months) to low (hours or minutes) and from fast (able to respond instantly or in seconds) to slow (hours or days).



Train-and-giant-concrete-block-based energy storage. | (ARES)

Each dispatchable resource will have slightly different value to grid operators, depending on conditions and time of day.

Big dispatchable supply sources can cover for VRE that’s unexpectedly low for weeks or even years.

Dispatchable demand is still in a nascent, rapidly developing phase, and at least for now it’s relatively slow and low capacity, but that will change; it will get fast, though how big is still an open question.

The biggest energy storage currently running (pumped hydro) can typically only cover a few hours of demand, but smaller storage can cover for hourly or minute-by-minute swings in VRE.

Here's where we come up against the dispute. Will we need nuclear and CCS to provide balancing, or can we do it without them?

To nuke or not to nuke?

The folks at the Solutions Project claim that we can — and, on the basis of a full cost-benefit analysis that takes all environmental impacts into effect, should — balance out VRE without recourse to nuclear power or CCS. (Jacobson also excludes biomass, though several other 100 percenters disagree with him on that.)

Doing that will involve three things. One, VRE will have to be massively overbuilt. Because its "capacity factor" (the amount of time it's running) is relatively low, to fully meet demand, total capacity will have to far exceed total demand, by multiples.

Two, transmission lines will have to be extended everywhere across the globe, to link VRE sources with demand and smooth out supply. And distribution grids will need to be upgraded. Quickly.

And three, remaining dispatchable resources — demand management, storage, hydro, maybe biomass — will have to be radically, radically scaled up. In particular, storage is going to have to grow exponentially.

On the other side of the dispute are people, many of whom are energy researchers, who simply don't believe that the above scenario is feasible, or if it is, that it's the most economic or effective way to get to zero carbon. They say nuclear and CCS should stay on the table.

The Kemper CCS project in Mississippi, now wildly overbudget. | (Wikipedia)

This is a heated and complex debate. I won't presume to settle it, but in my next post I'll get into some of the literature* and the back and forth and try to draw some tentative conclusions.

For now, though, it's enough to understand the shape of the problem, which is, after all, one of the core challenges facing humanity in the 21st century.

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*If there are studies or reports on this subject that you've found helpful, drop me a note: david@vox.com.

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