Recently the New York Times published an article chronicling the financial problems experienced by one of the world's premier developers of concentrated solar power (CSP) facilities. The financial headwinds facing CSP are a sign of a more fundamental problem electricity markets face: namely, capturing all of the important values we attach to electricity production.

Most utility-scale solar and wind farms are owned by independent power producers (IPPs), not traditional investor-owned utilities (IOUs), and the prevailing wisdom in the energy policy community is that IOUs stand as an obstacle to the greening of the energy mix. Indeed, parts of the United States that tend to rely on traditional IOUs (and therefore eschew competitive electricity markets) tend also not to have policies favoring utility-scale renewables.

But markets struggle to incentivize green energy as well. Competitive electricity markets do not distinguish between a kilowatt hour (kwh) of electricity from a green source versus a dirty source. Hence environmental regulation, and the smorgasbord of federal, state and local policies designed to encourage renewables, including renewable portfolio standards, tax credits, rebates and the like.

As the march toward more renewable electricity proceeds apace, a second problem will begin to rear its head: namely, that markets also do not do a good job of ensuring reliability in a high-renewables or all-renewables grid, because they do not yet distinguish effectively between a kwh of electricity from a reliable (dispatchable) source versus an intermittent (non-dispatchable) source.* This works to the disadvantage of three relatively green, dispatchable technologies: CSP, pumped-storage hydropower, and nuclear power.

Why does this matter? Because reliability has always been the first imperative of the electric system, and in order to serve that imperative intermittent resources like photovoltaic (PV) solar and wind must be backed up by other forms of generation. Someone will have to build and own that backup generation. If we aspire to an all-renewables future, we may need some CSP, pumped storage hydro, and nuclear power to realize that objective.

Electricity cannot be stored in commercial quantities at reasonable cost, so grid operators must continuously balance the amount of power being generated to match minute-to-minute changes in demand. They do so by dispatching the least expensive sources of power (by marginal cost) first. Zero-marginal cost sources like wind power and solar power tend to be dispatched whenever they are generating electricity, before other sources. This complicates grid operators' balancing task, because it requires them to ramp dispatchable sources up and down more often — not simply to follow variability in demand, but also variability in the

amount of power coming from wind and solar farms.

Only when all of this increased variability threatens the overall security of the grid does reliability matter in the dispatch algorithms. In those instances, wind or PV solar power may be curtailed in favor of more reliable sources, usually fossil fueled or nuclear generation. Those instances are rare, but will become less rare in high-renewables system. If the decline in American nuclear and coal-fired capacity continues, the balancing task will become increasingly difficult. Some proponents of rapid, deep decarbonization sidestep these reliability problems in their visions of the future.

If we could plan a green, reliable grid, we might want that grid to include more dispatchable, zero-emission generation like CSP, pumped storage hydro and nuclear power. Unlike PV solar, CSP can store energy for dispatch after sundown, or even the next morning. Pumped storage hydroelectric power stands ready to dispatch electricity to the grid when needed, unlike most conventional, run-of-river hydroelectric power which is dependent on unpredictable stream flows. And of course nuclear power scores higher on reliability than any other electricity source, save perhaps coal-fired power.

Of course, these sources face their own sets of environmental or safety objections, as do wind, PV solar farms, and conventional hydro, for that matter. But CSP, pumped storage hydro and nuclear offer the zero-emission attributes of wind, solar and conventional hydro, but with greater reliability.

Not coincidentally, these three sources tend to be more expensive than wind, solar and conventional hydro on a marginal cost basis, and make less money selling power in competitive markets. These sources tend to receive little or no credit in competitive markets for being both green and reliable. Traditional regulatory regimes, by contrast, guarantee IOUs a fair return on prudent investments in generation, and so could incentivize clean, reliable generators in ways markets have not, so far.

Thus, one finds new nuclear construction only in states like South Carolina and Georgia, which operate under traditional regimes that guarantee investors a fair return on investment. It is also part of the reason why the states like New York and Illinois, with competitive wholesale electricity markets, have recently considered making payments to existing nuclear power plants to persuade them to remain online even as they face difficulties competing in competitive markets. It may also be why despite a years-old queue of new pumped storage hydroelectric facilities awaiting licensing by the Federal Energy Regulatory Commission, few if any will be built. Their owners know that the plants will be unlikely to capture the full value of the clean, reliable power they provide in competitive

electricity markets.

It's ironic, then, that competitive electricity markets predominate in parts of the country that most favor decarbonization. The exception that proves the rule seems to be Vermont, the only northeastern state *not* to embrace competitive electricity markets. Vermont has no commercial fossil generation within its borders, hosting only renewable generators;± and it has been able to use its regulatory leverage over IOUs to offer attractive financing terms for energy efficiency improvements there.

The problem of pricing reliability and environmental performance in competitive electricity markets is a vexing one. Competitive electricity markets may yet devise ways to price reliability and environmental performance accurately, but right now they seem to struggle with that task in ways that complicate the decarbonization of the electricity sector.

* Some argue mandatory dynamic or real-time pricing, in which retail rates vary to reflect the momentary value of electricity at different grid locations, would incentivize reliability. This view is based upon a number of debatable assumptions too numerous to discuss here. In any case, dynamic pricing has been slow to catch on so far, and state policymakers show little appetite for forcing it on ratepayers.

± These consist of wind, solar, biomass and hydro. The Vermont Yankee nuclear station is closing. Vermont consumes electricity off of the broader New England system, however, and so consumes some fossil-fueled electricity. It's renewable portfolio standard establishes a goal of consuming 20 percent renewables by next year.

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