Reliability and Resilience: Complements or Substitutes?

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Since the 1965 New York City blackout, "reliability" has been the policy and operational watchword for the concept for confidence that the lights will come on. In more recent years, the term "resilience" has come to the fore. From my vantage point, it looked initially like "resilience" was a term invented by the Trump Administration's Department of Energy to justify proposed regulations to protect coal-fired electricity generators from market forces that have made them increasingly unprofitable, apart from any emissions or carbon regulation. I thought this in part because at first glance the difference between "reliability" and "resilience" was far from clear.

Nevertheless, "resilience" persists, and has become much more widely used. Whether it has a different meaning than reliability remains unclear. For example, when using "climate resilience" to refer to the ability of a grid to withstand climate-related distress, the term "climate reliability" would be equally suitable. Presumably, however, resilience is more than a fashionable synonym for reliability, which perhaps had become mundane over the last 65 years.

Rather, I will infer that this different term has become prevalent because it has a definition separate from reliability. From the dictionary, the defining characteristic of resilience is the ability to recover from a shock. To be a little more precise, we can define resilience of an electricity grid or system as the probability that grid will be running at some time interval (minute, hour, day) following an outage. A measure of resilience under this definition would be the average or expected duration of an outage; the more resilient a system, the shorter that duration. Whether the cause of the outage is a random internal failure, like a generator going unexpectedly offline, or a random external event, like weather blowing down a transmission line, is immaterial to this definition here, although in practice a system can be more resilient to some outages than others, depending on the cause.

This invites a second concept that contributes to the overall expected performance of a grid: the probability that the grid will still be running at some time interval after it was already running. The relevant measure here would be mean time between failures. Again, whether the cause of that failure was internal or external is immaterial at this simple level. With some trepidation to be explained below, I will use "reliability" to refer to this idea, that is, that the longer the mean time between failures, the more reliable is the system.

The question posed here is whether reliability and resilience are complements or substitutes. The usual presumption seems to be that resilience goes hand in hand with reliability. This may be true, but I want to suggest that it need not be true—a more reliable system may be less resilient, and a more resilient system may be less reliable.

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Seeing this requires some notion of the object of the game. Keeping things simple, suppose that the goal of the electricity grid operator or regulator is to maximize the probability that the grid is running, or in other words, reduce the chance of an outage at any given time. The overall probability that a grid is running will thus depend on both reliability and resilience. The more reliable, by this definition, the less frequent will be outages. The more resilient, by this definition, the shorter will be the time the outage lasts.

Of course, not all outages are equally costly. Losing power during extreme weather events when one needs heat (if just the fan to circulate air heated by a gas furnace) or air conditioning will be more important to avoid than when circumstances are less threatening. Losing power during the workday will be more costly, generally, than the middle of the night. In actuality, a grid operator or regulator will care about these as well. Taking those complications into account would change specifics in practice, but the fundamental question of whether resilience and reliability could conflict with each other remains.

At one level, reliability and resilience may be substitute means for maximizing the overall likelihood of performance or, alternatively, minimizing the possibility of an outage. A grid operator or regulator interested in cost efficiency would choose to invest in reliability and resilience up to the levels where the incremental benefit to overall performance per dollar on methods to improve reliability would be the same as investments to improve resilience. However, that is consistent with the possibility that reliability investments improve resilience, and *vice versa*. It's just that methods to best target one may not be the same as methods to best target the other.

I want to raise the possibility, however, that the conflict may not just be on the best way to invest in one or the other, but that investing more in one reduces the other. Making a system more reliable may make the system less resilient, and making a system more resilient may make it less reliable.

The key idea involves repair. Systems that are harder to disrupt—more reliable—may also be harder to repair—less resilient. Compare cars of today to cars of fifty years ago. The latter were less reliable, but more resilient, at least for the many people with the interest and skill to fix cars themselves.

The most apparent example from the grid is burying distribution and transmission lines. Burying lines makes them more reliable, in that underground lines are less vulnerable to weather-related disruptions than above-ground lines. However, if something does go wrong with a buried line, it may take longer to repair than lines on poles, where damage is easier to detect and without digging required to repair it. Another possibility may be shutting down transmission lines during very hot weather—reducing reliability—to prevent fires that would delay restoration—promoting resilience.

There may be other examples; I am not a grid engineer. But the point is that proposals to increase resilience, tempting as those may be, could come at the cost of reduced reliability. One should be careful before giving in to that temptation. More resilience will promote grid performance "all else equal," but the nature of investments to promote resilience may keep all else—reliability—from being equal.

Before leaving, I return to that trepidation on terminology that I mentioned above. The framework here is simple, based on how long it takes to repair a grid that goes down, and how infrequent are such repairs necessary. Calling the first "resilience" seems pretty clear. Here, I defined "reliability" as the probability that a grid once operating will keep operating, with no term for the overall probability that the grid operates, taking both resilience and reliability so defined into account. If one likes long words beginning with an "r", perhaps "robustness" would be a good term for this overall probability.

Alternatively, one could define "reliability" as this overall probability of operation. We would then need another term for this "mean time between failures" concept. Perhaps "stability" would be a good one, although that may already be a term of art among grid engineers. Then, the central point of this paper would be that increased resilience might conflict with stability, and thus at some point reduce reliability as well.

I leave the choice of nomenclature to readers with more engineering expertise than I have. But whatever one decides to label as reliability, designing a system to increase resilience—reduce the expected time to restore power once an outage occurs—need not improve the overall performance of an electricity grid.

Footnotes

* I thank Karen Palmer for helpful comments. Remaining errors are my sole responsibility, and these views do not necessarily reflect those of anyone else at RFF.