Unraveling grid defection: The game theory behind our shifting energy landscape

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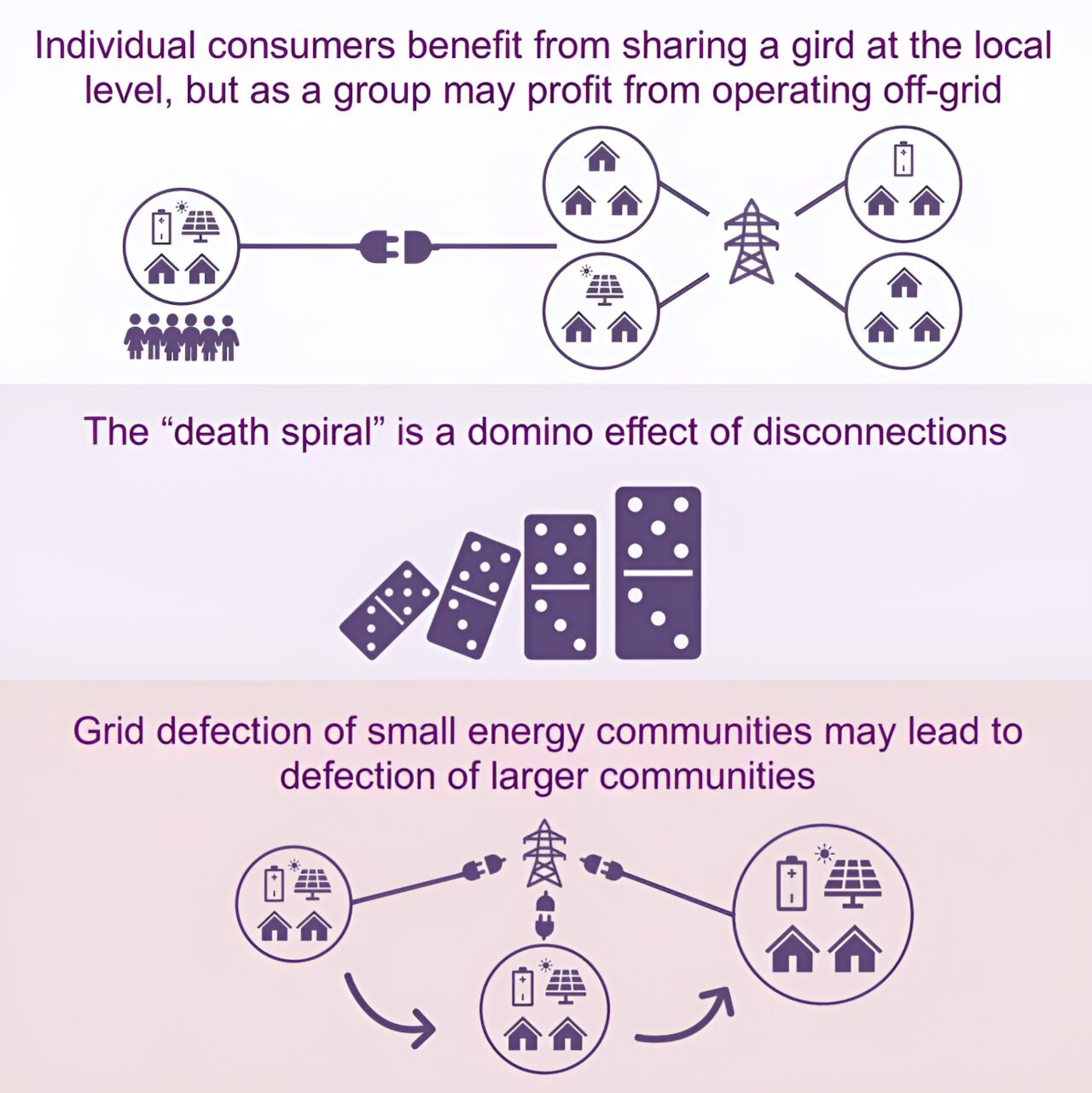

Although individual consumers benefit from staying connected at the distribution level, the defection of small energy communities from the grid may lead to the defection of larger communities, causing a so-called domino effect and a death spiral. Credit: Aviad Navon

Grid defection occurs when it's cheaper for consumers to produce their own power than to buy it from the grid. For example, if a consumer faces high monthly utility fees regardless of their actual usage and can generate power using affordable local generators, they might choose to disconnect from the grid. On a large scale, this trend could lead to significant changes in how electric grids function, which needs to be better understood and managed.

Local energy systems, such as microgrids and energy communities, are crucial to transitioning to renewable and decentralized energy systems. For instance, in Europe, there are more than 7,700 energy communities with over 2 million members adopting DERs, often with independent electricity prices for their members. As costs decrease, these local systems could develop enough resources to become energy autonomous and choose to defect from the grid.

However, grid defection can have major negative effects. It might slow the transition to a low-carbon economy by making it harder to justify the investment in grid expansions needed to support renewable energy. Recent reports suggest massive grid expansions to support renewable energy integration, with global costs estimated at hundreds of billions of dollars annually. Grid defection threatens the cost recovery of such projects.

Moreover, if too many consumers leave the grid, those remaining might face higher electricity bills, leading to economic inequality. This may happen if a portion of consumers leave the grid, and those who are left behind, and perhaps do not have the ability to generate their own electricity, will pay significantly higher electricity bills.

Another far-reaching consequence of grid defection is the "utility death spiral," where electric utilities face financial collapse due to a positive-feedback loop: as consumers leave the grid, electricity prices rise, causing even more defections. If this cycle continues, the centralized power system could be replaced by a less stable decentralized structure, jeopardizing energy security, system reliability, and price stability.

Understanding the complex dynamics of grid defection with a game-theoretic approach

To tackle the challenges posed by grid defection, a recent study introduces a novel game-theoretic framework that delves into the strategic behavior of consumers with conflicting interests. This approach offers new insights into how grid defection unfolds. The study is published in the journal *iScience*.

The study highlights that ignoring the inter-dependencies among consumers when making grid design decisions can lead to inefficiencies and unpredictable defections. One key finding is that defection rates don't simply rise linearly as the cost of going off-grid decreases. Instead, they increase non-linearly, with sudden spikes under certain cost conditions. These spikes are driven by "conditional defection," where consumers decide to leave the grid only because others have done so.

Moreover, the defection of smaller consumer clusters can trigger larger clusters to defect, creating a domino effect that evolves over time. This phenomenon can significantly raise electricity costs for those who remain connected, comparable to the impact of "unconditional defection." Understanding these dynamics is crucial for policymakers to make informed decisions that protect social welfare and maintain a stable energy grid.

The study also finds that the physical characteristics of the electric grid play a crucial role in its susceptibility to defection. In particular, distribution grids—such as those serving neighborhoods or cities—are generally resistant to defection. This is because consumers gain significant benefits from sharing electricity within these localized networks. However, when it comes to transmission grids, e.g., national scale grids, the risk of defection is more complex.

The vulnerability of these larger grids, which carry electricity over long distances, depends on factors like their length, complexity, and how the load is distributed across them. Understanding these physical influences is essential for designing grids that are resilient to the potential adverse effects of large-scale grid defection.

Rethinking grid expansion in a future of independent energy systems

Current grid expansion plans are based on the assumption that all consumers will remain connected, making these investments potentially vulnerable to grid defection. If consumers start defecting, these plans could face significant delays or might never be realized. By factoring in predictions of grid defection during the planning stages, grid expansion can be made more efficient.

For instance, policymakers could promote the development of independent microgrids in areas with a high likelihood of defection, thereby avoiding unnecessary and costly expansions. Moreover, utility companies could selectively provide off-grid services where it is economically advantageous to prevent grid defection.

In conclusion, the study underscores the critical role of consumer inter-dependency in driving grid defection, revealing potential hotspots that traditional methods might overlook. By incorporating defection processes and consumer interactions into demand prediction models, planners can make more informed decisions that account for the complexities of modern energy systems. This approach not only offers valuable insights into managing grid defection but also highlights the need to consider consumer diversity and behavior in the design of future energy infrastructures.

With a deeper understanding of grid defection dynamics, policymakers and utility companies can craft effective strategies to navigate the ongoing transition to a more decentralized energy landscape.

More information: Aviad Navon et al, Death spiral of the legacy grid: A game-theoretic analysis of modern grid defection processes, *iScience* (2023). DOI: 10.1016/j.isci.2023.106415

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