# THE ECONOMICS OF LOAD DEFECTION

## HOW GRID-CONNECTED SOLAR-PLUS-BATTERY SYSTEMS WILL COMPETE WITH TRADITIONAL ELECTRIC SERVICE, WHY IT MATTERS, AND POSSIBLE PATHS FORWARD


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# EXECUTIVE SUMMARY

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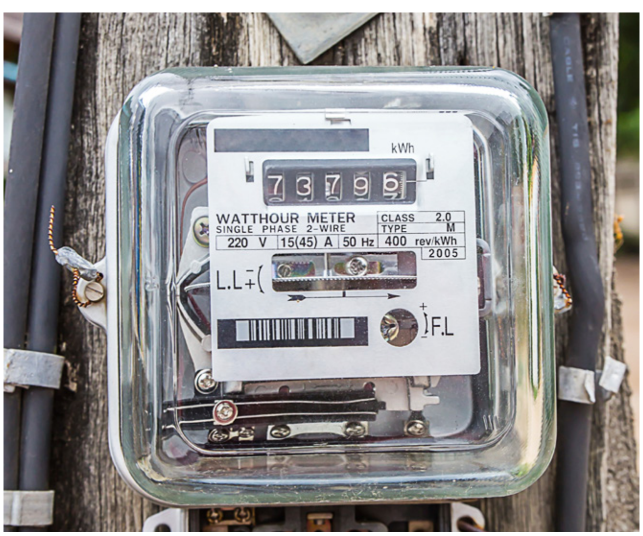
When *Greentech Media* published its annually updated list of cleantech buzzwords in December, its list for 2014 included “grid defection.”[1] Our February 2014 analysis *The Economics of Grid Defection* was a central piece of that conversation. We found that in the coming years and decades—and certainly within the economic life of new investments in conventional generation—large numbers of residential and commercial customers alike will find it economical to defect from their utilities and the electricity grid and supply themselves with power from solar-plus-battery systems. This finding foretold a future in which customers will have a choice to either cost-effectively self-generate without the grid or be a traditional customer with the grid.

While the presence of such customer choice has important implications, the number of customers who would actually choose to defect is probably small. The far more likely scenario is customer investment in *grid-connected* solar-plus-battery systems. Since such systems would benefit from grid resources, they could be more optimally sized, thus making them smaller, less expensive, economic for more customers sooner, and adopted faster. More specifically how system configurations and economics would evolve over time, and what magnitude of customers, load, and revenue that could represent, are the focus of this analysis.




## ANALYSIS

In particular, we sought to answer two core questions:

1. ***Lowest-Cost Economics:*** When grid-connected customers have the option to source their entire load either from a) the grid, b) a solar-plus-battery system, or c) some combination of the grid, solar PV, and batteries, how does that configuration change over time based on lowest-cost economics for the customer? And how do the relative contributions of grid- and self-sourced electricity change over time to meet customer load?
2. ***Implications:*** What are the potential implications for utilities, third-party solar and battery providers, financiers/investors, customers, and other electricity system stakeholders? And what opportunities might be found in grid-connected solar-plus-battery systems?

We evaluated the economics through 2050 for a median commercial and residential customer in five cities that represent a diversity of electricity pricing and solar resource intensity. We modeled forecasts for grid only, grid-plus-solar, and grid-plus-solar-plus-battery configurations to find the lowest-cost option over time (based on systems’ per-kWh levelized cost of energy equivalent). We also examined the relative contributions of grid- and self-supplied electricity for the lowest-cost option over time. For solar and solar-plus-battery configurations, we modeled largely self-consuming systems with no export compensation (i.e., optimized for behind-the-meter operation). Although export compensation via bill credits or direct payments (e.g., net energy metering, feed-in tariff, avoided fuel cost compensation) is today present in most geographies and would improve the economics presented here, we assumed no bill credit or direct compensation for exports as a conservatism to understand the economic implications in the most extreme case.

## FINDINGS

Our analysis yields several significant findings:

### *Solar-plus-Battery Systems Rapidly Become Cost Effective*

The economically optimal system configuration from the customer's perspective evolves over time, from grid only in the near term, to grid-plus-solar, to grid-plus-solar-plus-batteries in the longer term. Compared to the date of economic parity for the off-grid solar-plus-battery systems we modeled in *The Economics of Grid Defection*, the grid-connected systems of this analysis become economic for customers much sooner, with substantial utility load loss well within the economic life and cost recovery period for major assets. Smaller solar-only systems are economic today in three of our five geographies, and will be so for all geographies within a decade. New customers will find solar-plus-battery systems configurations most economic in three of our geographies within the next 10–15 years.

**FIGURE ES1:**
ECONOMICALLY OPTIMAL SYSTEM CONFIGURATION
RESIDENTIAL

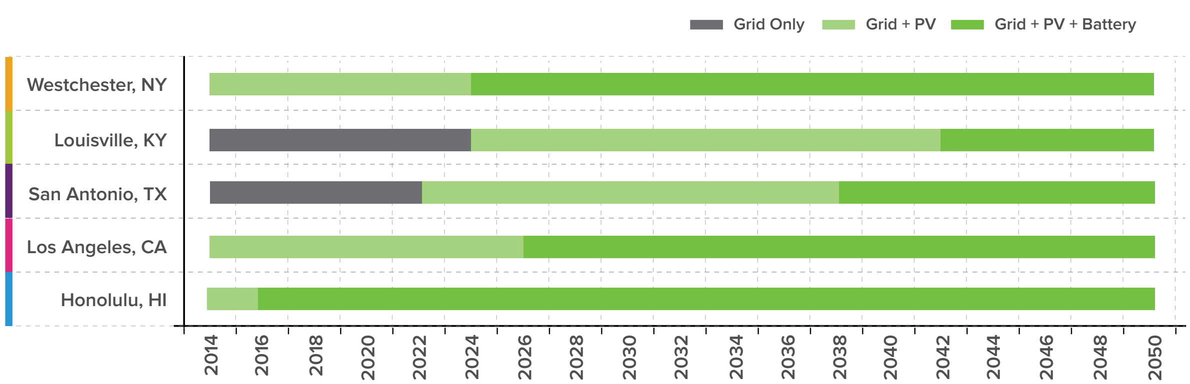
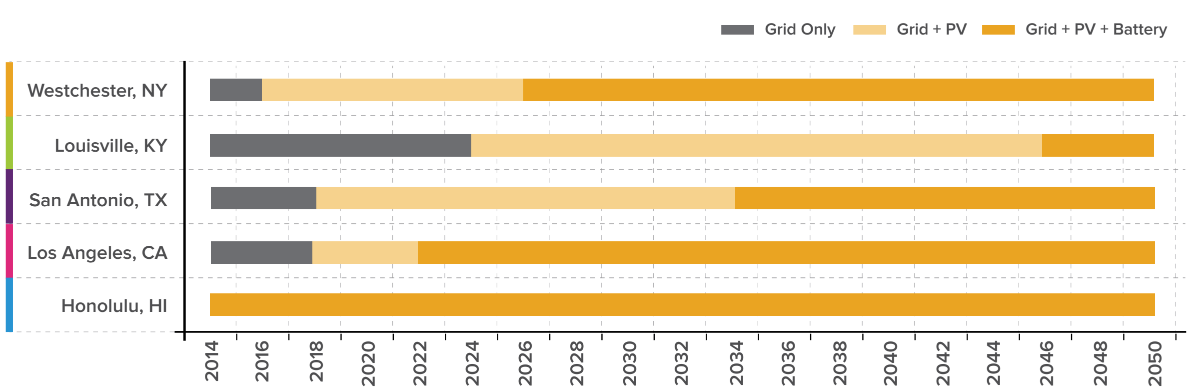



**FIGURE ES2:**
ECONOMICALLY OPTIMAL SYSTEM CONFIGURATION
COMMERCIAL

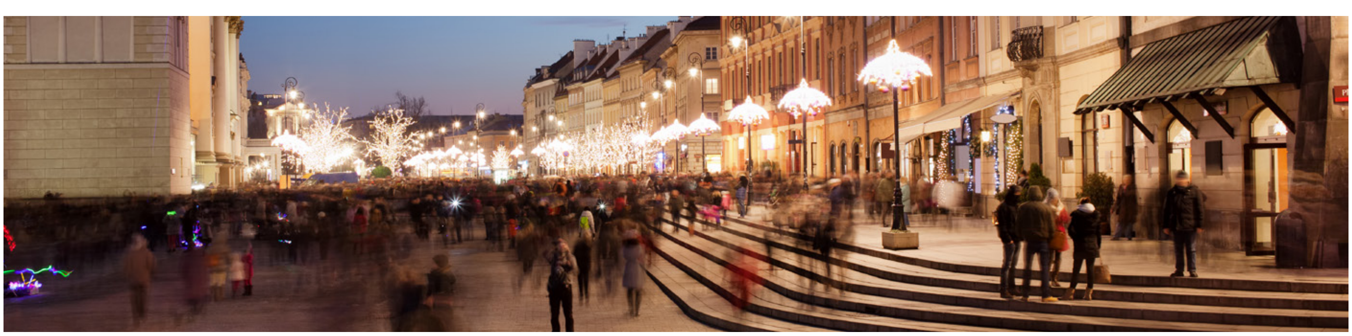


### *Solar PV Supplants the Grid Supplying the Majority of Customers' Electricity*

The relative contributions of the grid and customers' solar and solar-plus-battery systems evolves over time. Initially the grid supplies a majority of a customer's electricity needs. Over time, as retail electricity prices from the grid increase and solar and battery costs decrease, customers logically reduce their grid purchases until the grid takes a backup-only role. Meanwhile, solar-plus-battery systems eventually provide the majority of customers' electricity. For example, in Westchester County, NY, our analysis shows the grid's contribution shrinking from 100% today for commercial customers to ~25% by around 2030 to less than 5% by 2050. Inversely, solar PV's contribution rises significantly to make up the difference.

**FIGURE ES3:**
ECONOMICALLY OPTIMAL GENERATION MIX
**RESIDENTIAL**


**FIGURE ES4:**
ECONOMICALLY OPTIMAL GENERATION MIX
**COMMERCIAL**

*Artur Bogacki/Shutterstock.com*

### *Potentially Large kWh Defection Could Undermine Revenue for Grid Investment Under Current Rate Structure and Business Models*

Between 2010 and 2030, the grid will require up to an estimated $2 trillion in investment, or about $100 billion per year.[2] Currently those costs are to be recovered through revenue from energy sales. If even a small fraction of the kWh sales supporting that investment and revenue is lost, it will likely have a large impact on system economics.[3] Notably, our analysis shows that grid-connected solar-plus-battery systems become economic for large numbers of customers, and those systems have the potential to supply greater and greater portions of customers' electricity. Assuming customer adoption follows optimal economics, the magnitude of potential kWh defection from the grid is large.

For example, in the Northeast U.S., by 2030—15 years away—maximum possible kWh sales erosion could be:

***Residential***

- ~58 million MWh annually (50% of utility residential kWh sales)
- 9.6 million customers
- ~$15 billion in revenue

***Commercial***

- ~83 million MWh (60% of utility commercial kWh sales)
- 1.9 million customers
- ~$19 billion in revenue

**FIGURE ES5:**
NORTHEAST POTENTIAL CUSTOMER DEFECTION
**RESIDENTIAL**

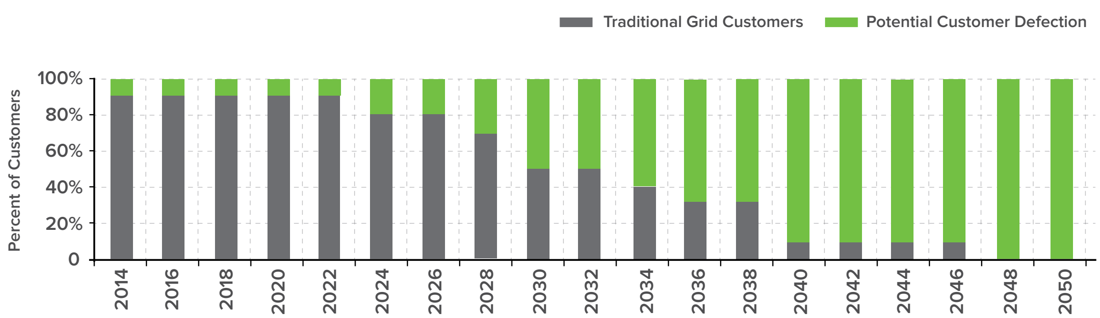



**FIGURE ES6:**
NORTHEAST POTENTIAL CUSTOMER DEFECTION
**COMMERCIAL**

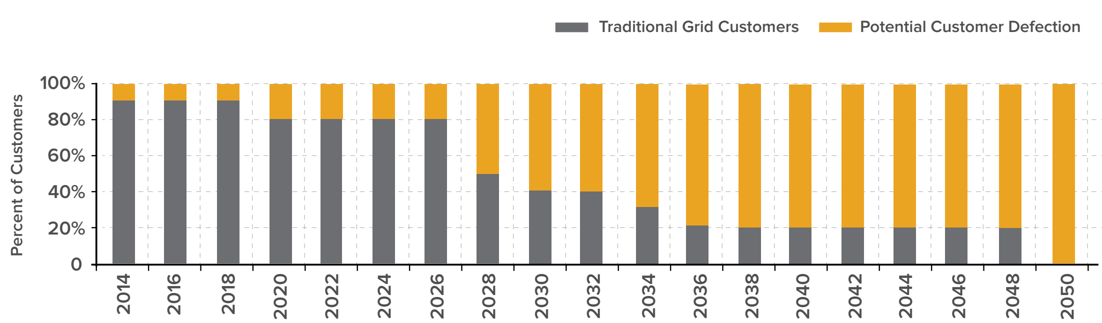


**FIGURE ES7:**
NORTHEAST POTENTIAL LOAD DEFECTION
**RESIDENTIAL**

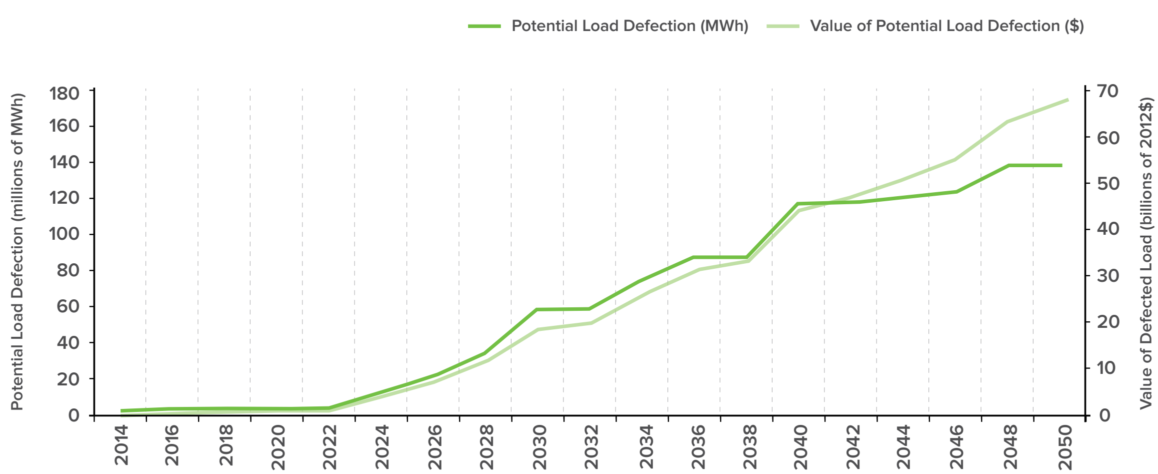
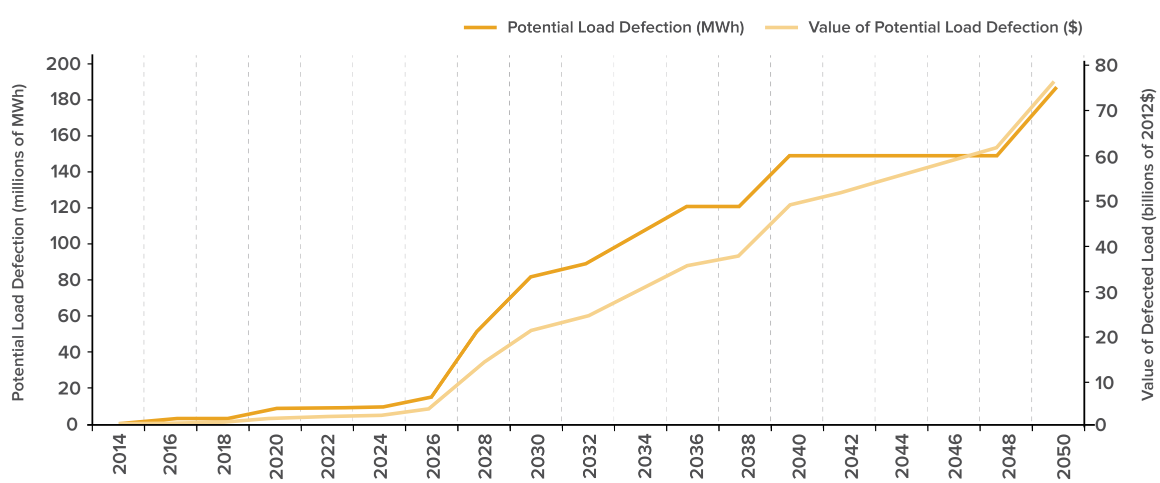



**FIGURE ES8:**
NORTHEAST POTENTIAL LOAD DEFECTION
**COMMERCIAL**



### *Eliminating Net Metering Only Delays kWh Loss; Fixed Charges Don't "Fix" the Problem*

Net energy metering (NEM) is a contentious yet prevalent policy that has successfully supported distributed solar PV's growth in the U.S. Some argue that it hastens load loss from the grid (net-metered solar PV customers quickly reach effectively zero net grid purchases) and that abolishing net metering will preserve grid load. Our findings suggest that eliminating net metering merely delays inevitable significant load loss. Grid-connected solar-plus-battery systems will gradually but ultimately cause a near-total load loss even in net metering's absence. However, fixed charges—which some utilities have recently proposed—don't 'fix' the problem. Similar to our "with" and "without" NEM scenarios, residential fixed charges would likely alter (i.e., delay) the economics for grid-connected solar and solar-plus-battery systems, but likely wouldn't alter the ultimate load defection outcome. Customers might instead wait until economics and other factors reach a tipping point threshold and more dramatically "jump" from grid dependence to off-grid solar-plus-battery systems that offer better economics for electric service.

**FIGURE ES9:**
NET GRID PURCHASES WITH AND WITHOUT NET METERING
RESIDENTIAL - **WESTCHESTER, NY**

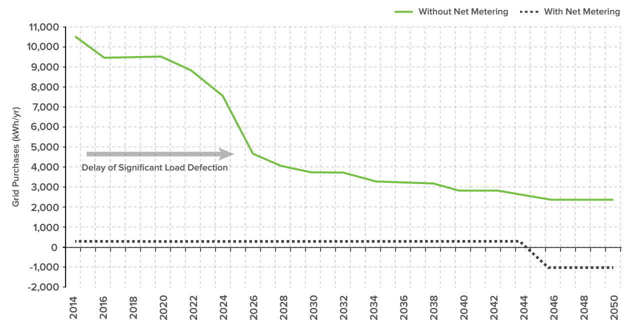
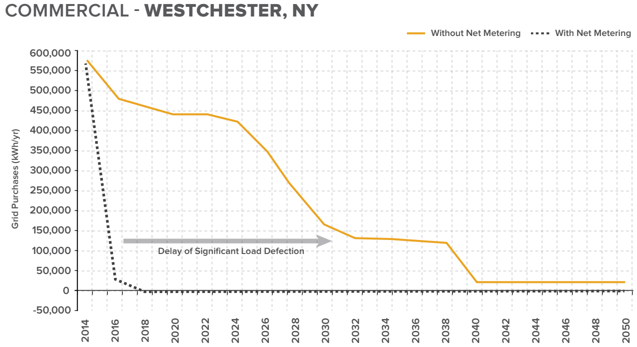


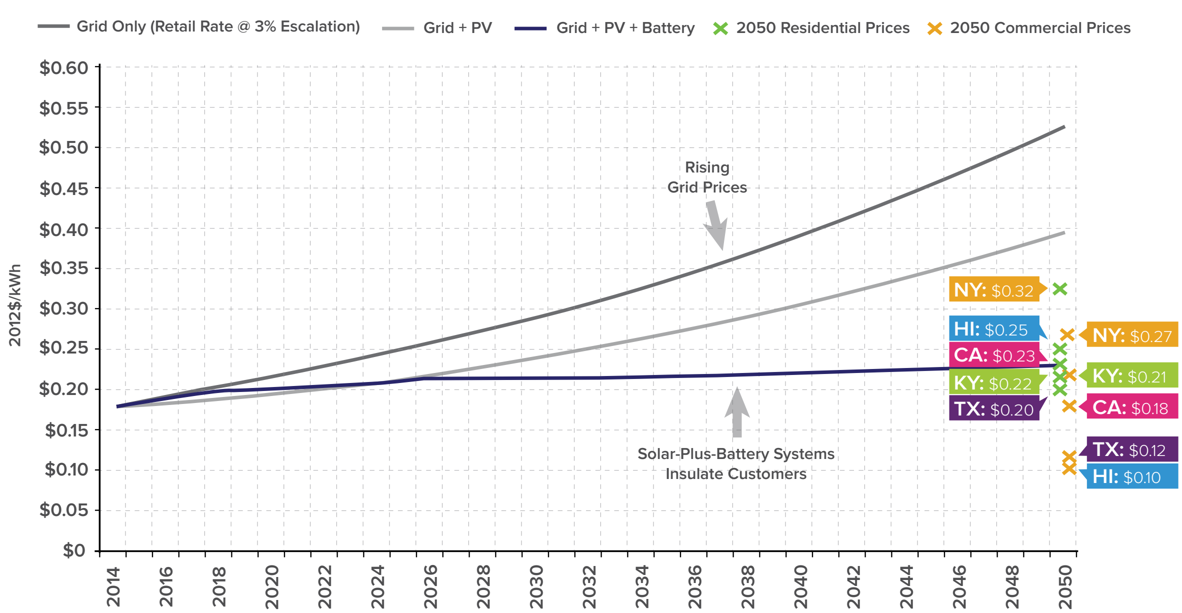

**FIGURE ES10:**
NET GRID PURCHASES WITH AND WITHOUT NET METERING
COMMERCIAL - **WESTCHESTER, NY**




### *Peak Price for Individual Customers*

Investing in their lowest-cost option for electric service through grid-connected solar and solar-plus-battery systems can effectively cap customers' electricity costs. No matter how expensive retail electricity prices get in the future, the levelized cost for grid-connected solar and solar-plus-battery systems keeps customers' bills at or below a 'peak price,' in some cases yielding a significant savings on their monthly utility bill. Peak per-kWh price stabilizes at $0.10–$0.30 for commercial customers and $0.20–$0.35 for residential customers across our geographies, regardless of how expensive grid-supplied retail electricity gets in the future. For example, for a median residential customer in Westchester County, NY, the average monthly electricity bill would reach $357 for grid electricity by 2030 based on forecasts, while peak price through adding a solar-plus-battery system would be just $268 per month. (Grid-facing costs such as T&D maintenance and central generation, as well as costs for grid-dependent customers who can't or don't invest in solar-plus-battery systems, are important related issues beyond the scope of this analysis.)

**FIGURE ES11:**
PEAK PRICE



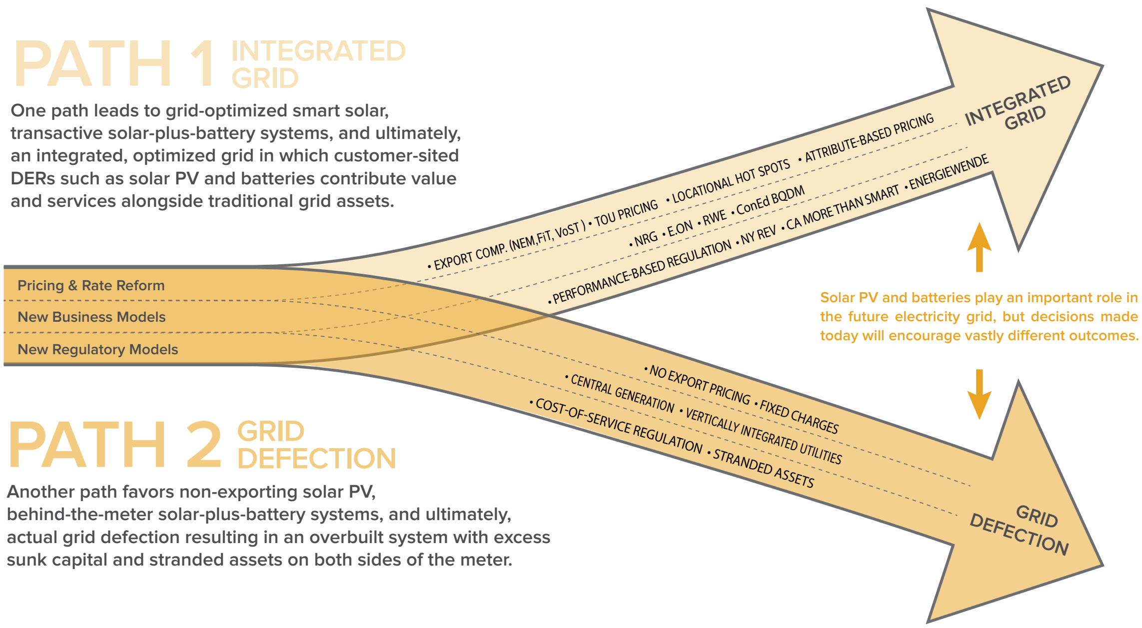
## IMPLICATIONS

Although our findings show that utilities' kWh sales loss to grid-connected solar-plus-battery systems could be very large, customer adoption of these systems also presents a number of opportunities. Unlike the off-grid systems we modeled in *The Economics of Grid Defection*, where customers left the grid entirely, the grid-connected customers of this analysis crucially *do maintain their grid connection* assuming that potential fixed charges and other changes to retail electricity price rate structures don't become so onerous as to encourage customer grid defection. This means that although they could represent significant load loss, customers' grid-connected solar-plus-battery systems *can potentially provide benefits, services, and values back to the grid*, especially if those value flows are monetized with new rate structures, business models, and regulatory frameworks.

The impact on various electricity-system market participants and other stakeholders will be profound and comes with a number of considerations:

- ***For customers that invest in solar PV and solar-plus-battery systems,*** the emergence of choice is good news. Our analysis suggests that, with smart solar-plus-battery investments, customers could see peak pricing emerge, insulating themselves from rising prices for grid-supplied electricity. Meanwhile, traditional grid-supplied customers and completely defected (i.e., off-grid) customers both had much higher pricing from rising retail prices and larger, more expensive stand-alone solar-plus-battery systems, respectively.
- ***For distribution grid operators*** (such as wires-only utilities), the emergence of distributed solar PV and batteries is good news: customers with solar and battery systems should be able to provide value to the distribution grid including upgrade deferrals, congestion relief, and ancillary services. However, new pricing, regulatory, and business models need to emerge and mature to capitalize fully on these opportunities.
- ***For owners and operators of central generation and transmission*** (such as independent power producers and merchant power plants), our findings are likely bad news. Our analysis predicts that solar-plus-battery systems will accelerate the decline of sales from central generation, reduce peak price spikes in deregulated markets, and also encroach on markets for ancillary services. There is a real risk of stranded assets. Existing assets still within their economic life and cost recovery period will serve a smaller and smaller remaining load, requiring price increases to cover costs and returns. Meanwhile, assets in the planning pipeline won't see the future demand to justify their capacity and generation output.
- ***For vertically-integrated utilities,*** these systems will strain current business models, and adjustments will be necessary to fully capitalize on the rising adoption of solar PV and batteries. Distribution utilities whose revenue depends on volumetric sales of electricity (e.g., that are not decoupled) will likely face similar challenges.

**FIGURE ES12:**
POSSIBLE TRAJECTORIES FOR ELECTRICITY GRID EVOLUTION




The electricity system is at a metaphorical fork in the road.

Down one path are pricing structures, business models, and regulatory environments that favor non-exporting solar and solar-plus-battery systems. When economic and other conditions reach the right tipping point, this trajectory favors true grid defection. In the meantime, an upward price spiral based on stranded assets serving a diminishing load will make solar-plus-battery adoption increasingly attractive for customers who can, and lead to untenably high pricing for customers who remain on the grid, including low- and fixed-income customers who would bear a disproportionate burden of escalated retail electricity pricing. In this future, both grid and customer-side resources are overbuilt and underutilized, leaving excess capital on both sides of the meter.

Down another path are pricing structures, business models, and regulatory environments in which distributed energy resources such as solar PV and batteries—and their inherent benefits and costs—are appropriately valued as part of an integrated grid. Solar PV and batteries can potentially lower system-wide costs while contributing to the foundation of a reliable, resilient, affordable, low-carbon grid of the future in which customers are empowered with choice. In this future, grid and customer-side resources work together as part of an integrated grid with far more efficient deployment of capital and physical assets.

These two pathways are not set in stone, and there is some room to navigate within their boundaries. But decisions made today will set us on a trajectory from which it will be more difficult to course correct in the future. The time frame for making such decisions with long-lasting implications for the future grid is relatively short, and is shorter and more urgent for some geographies than others.

Three distinct market phases define the window's time frame:

- ***Phase 1: An Opportunity to Experiment***
  In phase 1, the grid alone offers customers the cheapest option for electric service. Solar-plus-battery systems come at a cost premium, so early adopters and technology providers will experiment with systems to leverage secondary values such as reliability. This phase gives utilities and regulators the longest runway to consider how to best capture the opportunities of grid-connected solar-plus-battery systems.
- ***Phase 2: An Opportunity to Integrate***
  In phase 2, solar-plus-battery systems become economic relative to grid-supplied electricity. With more favorable economics for greater customer adoption, this is an ideal time for systems to create and share value between individual customers and the grid.
- ***Phase 3: An Opportunity to Coordinate***
  In phase 3, retail electric pricing has escalated enough and solar-plus-battery system costs have declined enough that the latter becomes economic to serve a customer's entire load and grid defection becomes a viable choice. Such compelling customer-facing economics make it especially urgent for utilities and regulators to adapt to this new market environment.

The electricity industry needs to act quickly on three fronts:

- ***Evolved pricing and rate structures:*** Today's rate structures are overly simplistic for the 21st century needs of the grid. Broadly, pricing needs to evolve in three critical ways:
  1. *Locational,* allowing some electric-grid equivalent of congestion pricing or incentives
  2. *Temporal*, allowing for continued evolution of time-of-use pricing and real-time pricing
  3. *Attribute-based,* breaking apart energy, capacity, ancillary services, and other service components
- ***New business models:*** Current business models need to evolve from the old paradigm of centralized generation and the unidirectional use of the grid (i.e., one-way electron flow from generators to consumers) to the emerging reality of cost-competitive DERs such as solar PV and batteries (i.e., grid-connected customers with behind-the-meter DERs and a two-way flow of electrons, services, and value across the meter). Creating a sustainable long-term DER market—considering the near and present opportunity of solar PV and batteries but inclusive of a much broader suite of DER technologies—will require aligning the interests of utilities, DER companies, technology providers, and customers. Aligning those interests requires that the value of DERs be recognized and shared on both sides of the meter.
- ***New regulatory models:*** Regulatory reform will be necessary for the electricity system to effectively incorporate new customer-sited technologies like solar and batteries as resources into the grid. Three critical outputs of these reforms are required to sensibly guide the adoption of solar-plus-battery systems in particular and DERs in general: 1) maintain and enhance fair and equal customer access to DERs, 2) recognize, quantify, and appropriately monetize both the benefits and costs that DERs such as solar PV and batteries can create, and 3) preserve equitable treatment of all customers, including those that do not invest in DERs and remain solely grid dependent.