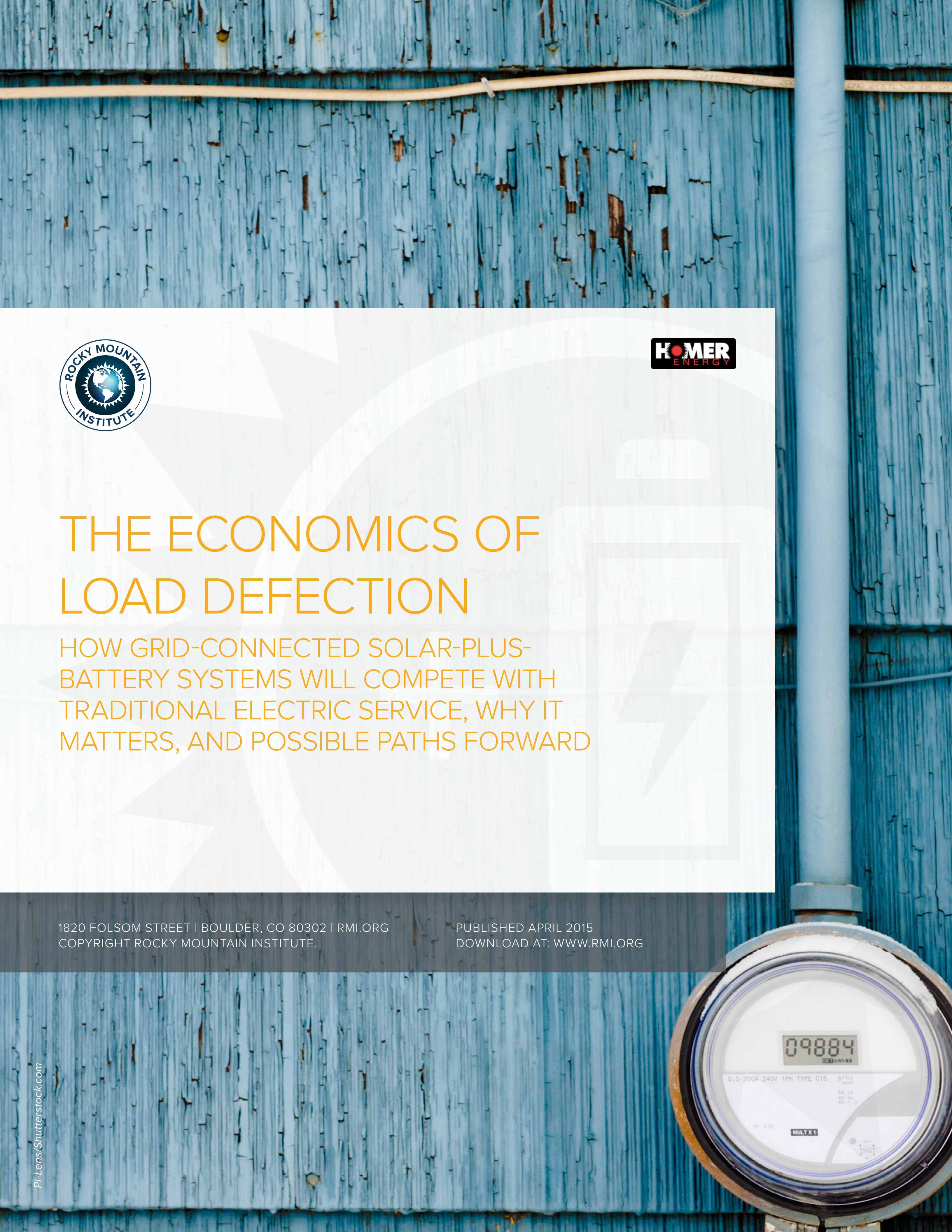

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THE ECONOMICS OF LOAD DEFECTION

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

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PUBLISHED APRIL 2015

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ACKNOWLEDGMENTS

The authors thank the following individuals and organizations for offering their insights and perspectives on this work:

Sunil Cherian, Spirae
Ali Crawford, Sacramento Municipal Utility District
Jon Fortune, Sunverge Energy
Lena Hansen, Rocky Mountain Institute
Tom Key, Electric Power Research Institute
Lee Kosla, Saft Batteries
Chris Kuhl, ZBB Battery
Virginia Lacy, Rocky Mountain Institute
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TABLE OF CONTENTS

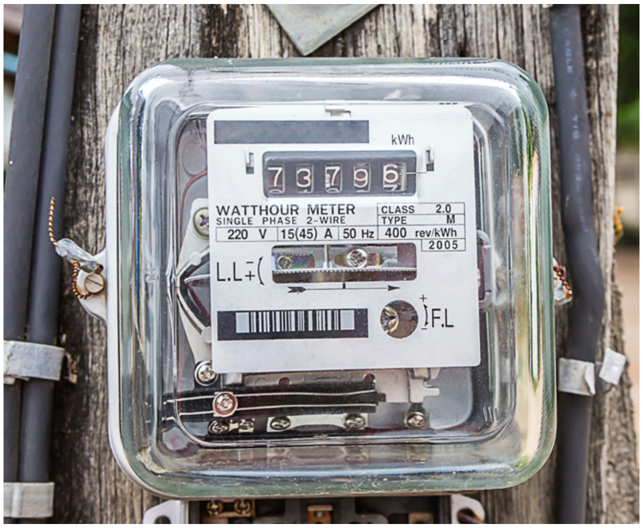
EXECUTIVE SUMMARY

EXEC

EXECUTIVE SUMMARY

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

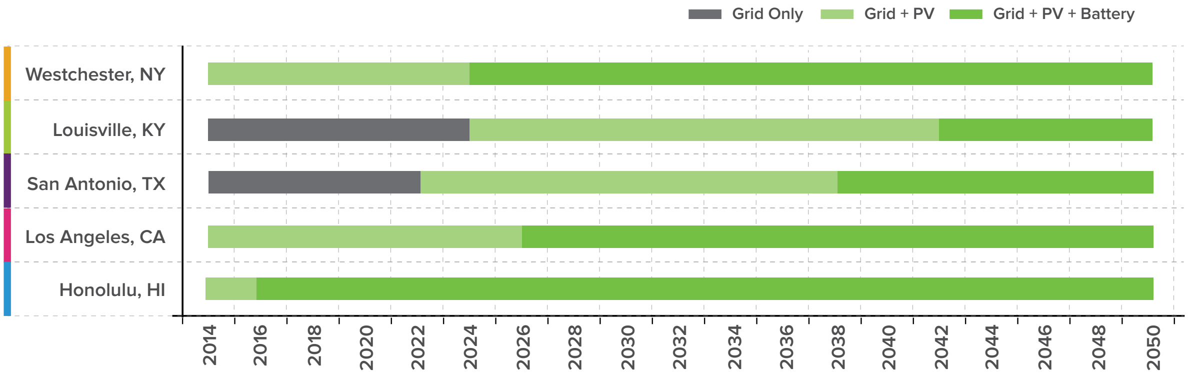
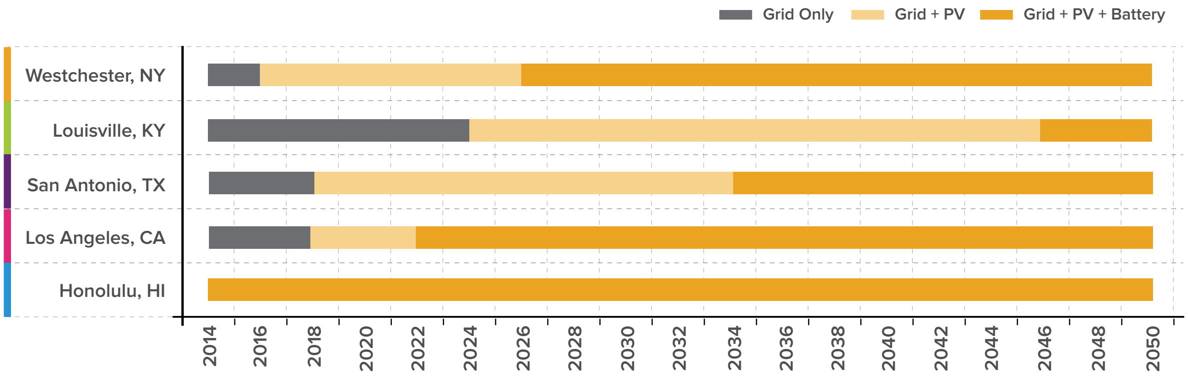


FIGURE ES2:
ECONOMICALLY OPTIMAL SYSTEM CONFIGURATION
COMMERCIAL



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

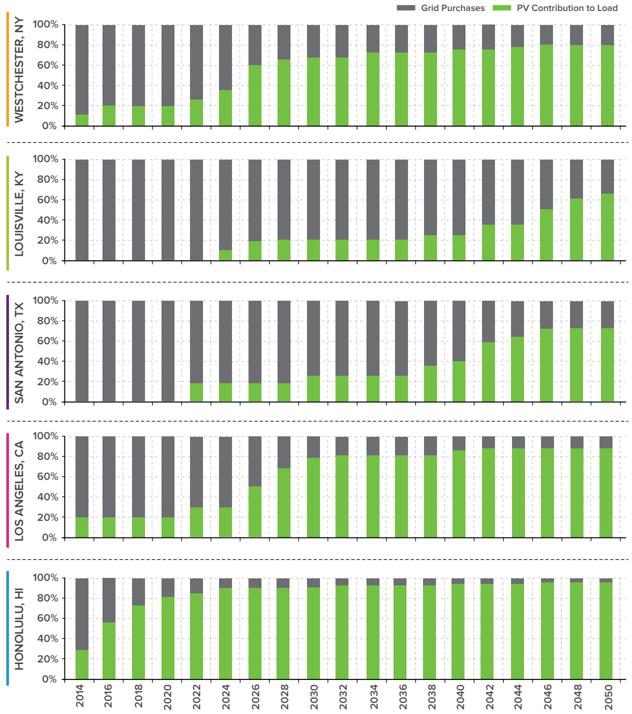


FIGURE ES4:
ECONOMICALLY OPTIMAL GENERATION MIX
COMMERCIAL

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

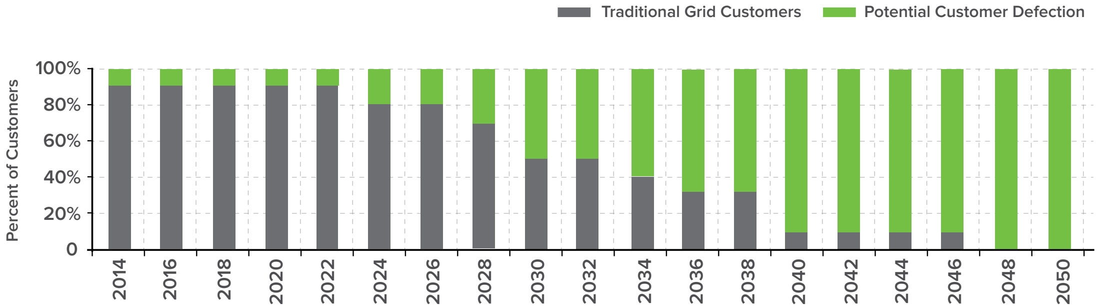


FIGURE ES6:
NORTHEAST POTENTIAL CUSTOMER DEFECTION
COMMERCIAL

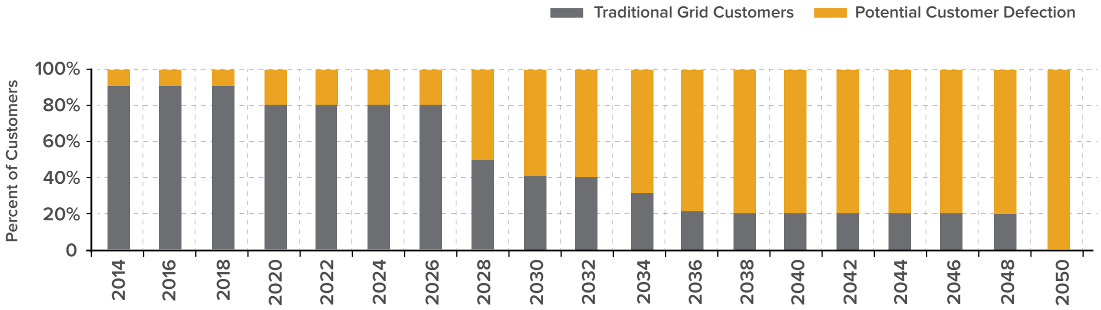


FIGURE ES7:
NORTHEAST POTENTIAL LOAD DEFECTION
RESIDENTIAL

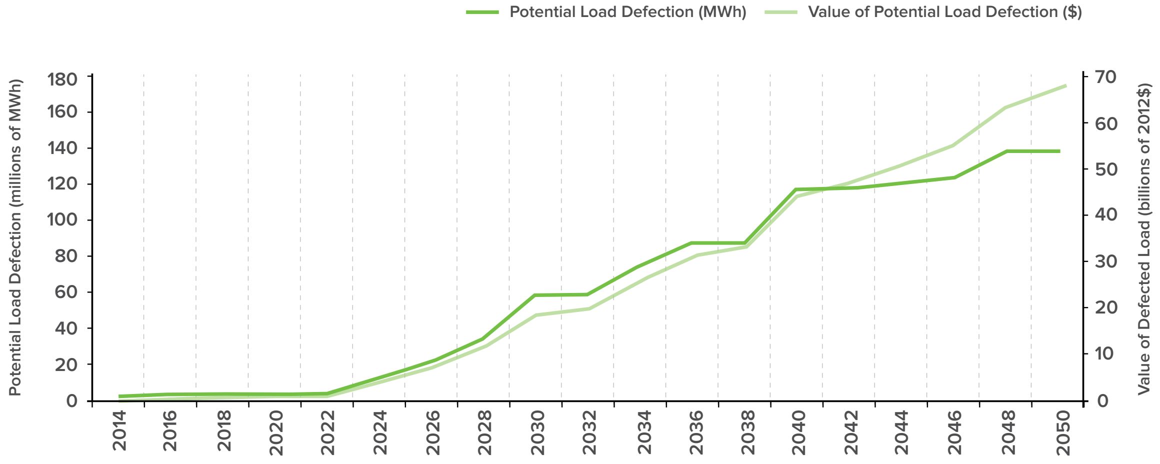
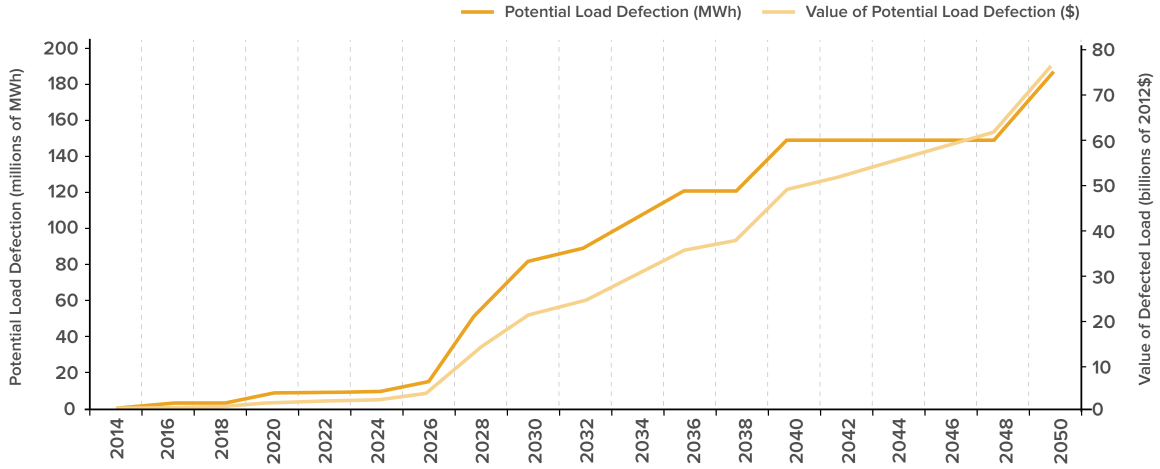


FIGURE ES8:
NORTHEAST POTENTIAL LOAD DEFECTION
COMMERCIAL



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**

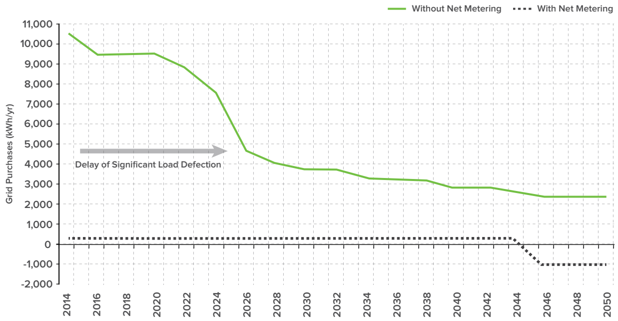
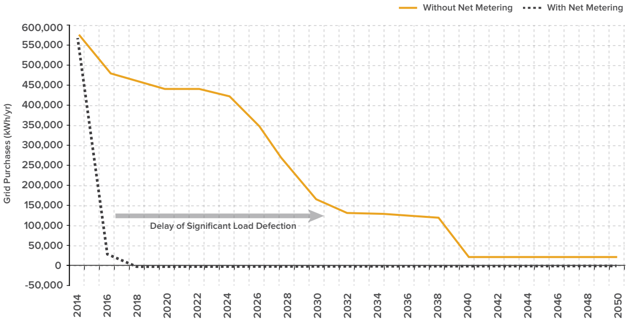


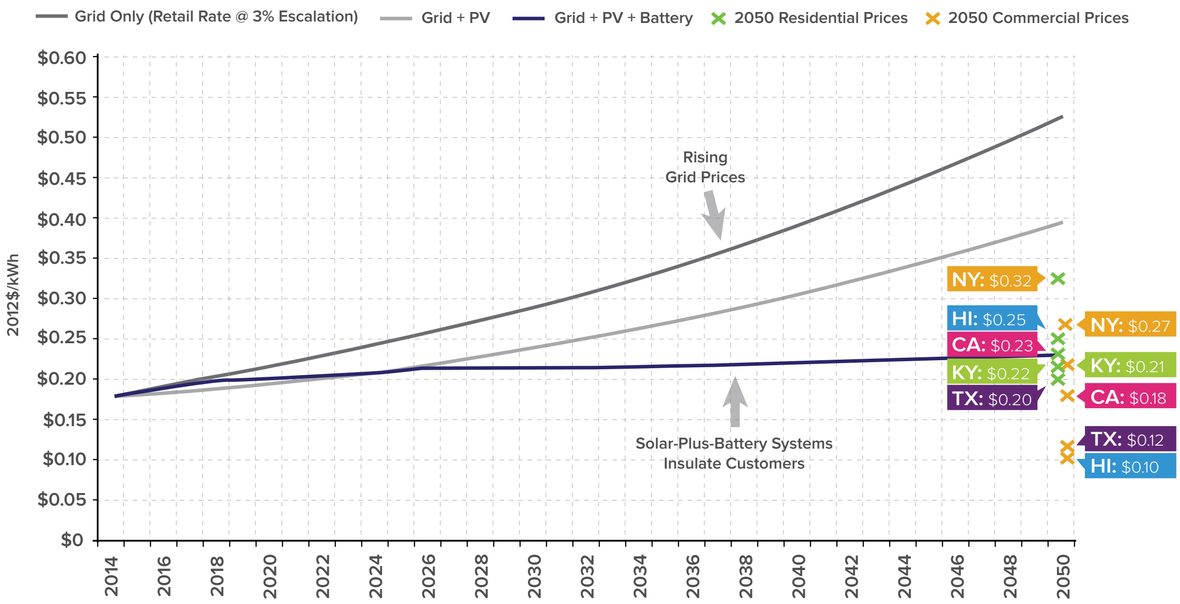
FIGURE ES10:
NET GRID PURCHASES WITH AND WITHOUT NET METERING
COMMERCIAL - **WESTCHESTER, NY**



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



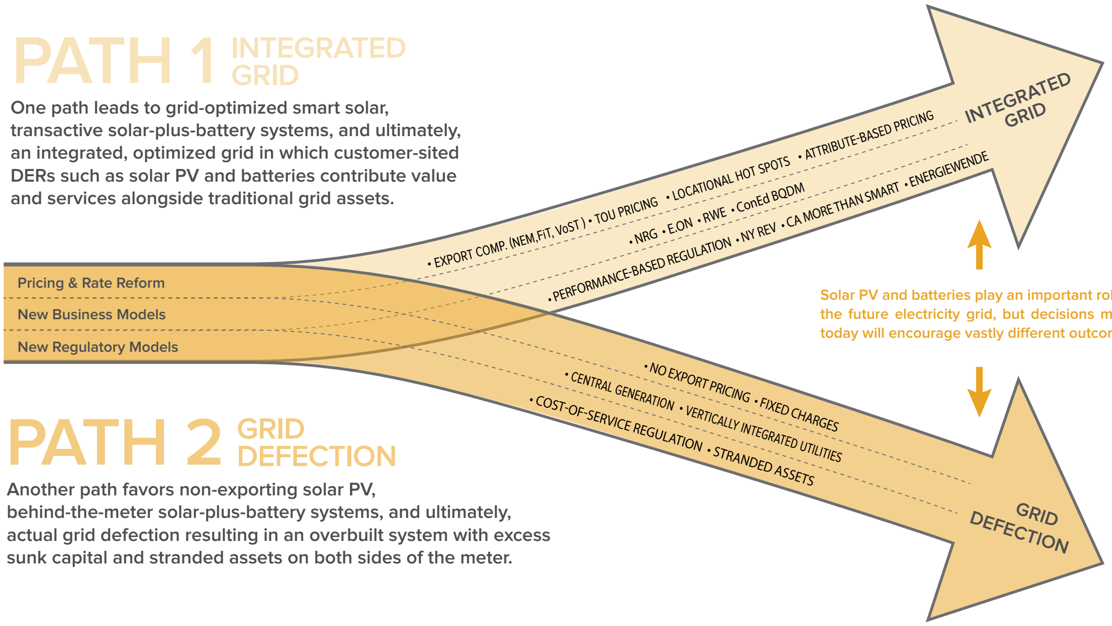
IMPLICATIONS

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



One path leads to grid-optimized smart solar, transactive solar-plus-battery systems, and ultimately, an integrated, optimized grid in which customer-sited DERs such as solar PV and batteries contribute value and services alongside traditional grid assets.

Solar PV and batteries play an important role in the future electricity grid, but decisions made today will encourage vastly different outcomes.

Another path favors non-exporting solar PV, behind-the-meter solar-plus-battery systems, and ultimately, actual grid defection resulting in an overbuilt system with excess sunk capital and stranded assets on both sides of the meter.

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.

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INTRODUCTION

01

INTRODUCTION

THE ELECTRICITY GRID IS EVOLVING

The electric industry in the United States is facing the greatest disruption in the grid's century-long history. The incumbent model of central thermal generation and one-way electricity distribution to end-use customers out on the grid's distribution edge is proving increasingly outdated. Rapidly growing adoption of customer-sited distributed energy resources (DERs) such as rooftop solar, battery energy storage, micro combined heat and power (CHP), electric vehicles, and smart thermostats that can communicate with and respond to grid signals are fundamentally changing the electric grid's landscape.

Utilities and other transmission and distribution grid electricity system stakeholders (e.g., ISOs, RTOs, etc.) have, to date, done an admirable job maintaining reliable, cost-effective electric service. But regulatory mandates, declining costs of distributed technologies, climate change, shifting customer preferences, and other motivating factors are driving the electric grid's evolution toward even more affordable, more reliable, more resilient, and lower carbon electric service, all while accounting for a new era of choice and empowerment with how individual customers produce and use electricity. DERs figure centrally in that evolution.

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DISTRIBUTED SOLAR-PLUS-BATTERY SYSTEMS ARE HAVING A PARTICULARLY ACUTE IMPACT

- *Rapid cost reductions with game-changing functionality:* Their continuing cost declines and unique operational characteristics make them particularly poised to gain favor among residential and commercial customers alike—and when grid connected, to provide value to the grid and society as well, and not just to the individual customer.
- *Accelerating commercial application and innovation:* Growing numbers of third-party providers are already offering such technology pairings to commercial customers to smooth load curves and lessen demand charges, while solar-plus-battery systems are also becoming increasingly appealing among early-adopter residential customers, especially in places such as the Northeast where the memory of blackouts after storms like Hurricane Sandy are still fresh.[4]

Until recently, the general media and industry experts both commonly claimed "electricity cannot be stored economically." Our analysis suggests that the fast-dropping costs of batteries, driven by their vast deployment in non-energy sectors (e.g., electronics, telecommunications, and automotive transportation) are showing otherwise.

Though not yet mainstream, solar-plus-battery systems are coming soon. Our February 2014 *The Economics of Grid Defection* report found that off-grid solar-plus-battery systems will reach grid parity in the coming years and decades in many geographies, within the 30-year time frame under which utilities typically recover costs on major grid investments.

THE FINANCE INDUSTRY IS TAKING NOTICE

In 2014, a chorus of analyses from major financial institutions—including Bank of America, Barclays, Citigroup, Fitch Ratings, Goldman Sachs, Morgan Stanley, and UBS (with several directly citing *The Economics of Grid Defection*)—found that solar-plus-battery systems pose a real and present threat to traditional utility business models. Their perspectives varied, but all echoed the common theme of increasing challenges for the current utility business model:

Morgan Stanley, Clean Tech, Utilities & Autos
March 4, 2014[5]

- *"Our analysis suggests utility customers may be positioned to eliminate their use of the power grid."*
- *"We expect ... batteries to be cost competitive with the grid in many states, and think investors generally do not appreciate the potential size of the market."*
- *"...we see the potential for customers to decide to move off-grid."*

Goldman Sachs, Analyst note on Tesla stock
March 2014[6]

- *"...decreased reliability from an aging distribution infrastructure, a broadening desire to reduce the carbon footprint, and perhaps most importantly, the reduction of solar panel and battery costs could also work together to make grid independence a reality for many customers one day...the conclusion is very clear – the potential for this application could be very large."*
- *"This puts [off-grid solar and storage] levelized cost of energy (LCOE) at $0.20 [per kWh] by 2033 which would be at parity with the U.S. grid price."*

Barclays, Utilities Credit Strategy Analyst Report
May 2014[7]

- *"In the 100+ year history of the electric utility industry, there has never before been a truly cost-competitive substitute available for grid power. We believe that solar + storage could reconfigure the organization and regulation of the electric power business over the coming decade. We see near-term risks to credit from regulators and utilities falling behind the solar + storage adoption curve and long-term risks from a comprehensive re-imagining of the role utilities play in providing electric power."*

Morgan Stanley, Solar Power & Energy Storage: Policy Factors vs. Improving Economics
July 28, 2014[8]

- *"...we think that customers in parts of the U.S. and Europe may seek to avoid utility grid fees by going 'off-grid' through a combination of solar power and energy storage. We believe there is not sufficient appreciation of the magnitude of energy storage cost reduction ... already achieved, nor of the further cost reduction magnitude..."*
- *"Over time, many U.S. customers could partially or completely eliminate their usage of the power grid. We see the greatest potential for such disruption in the West, Southwest, and mid-Atlantic."*

UBS, analyst note on EV and solar
August 2014[9]

- *"The expected rapid decline in battery cost by (more than) 50 per cent by 2020 should not just spur EV sales, but also lead to exponential growth in demand for stationary batteries to store excess power."*

- *“Our view is that the ‘we have done it like this for a century’ value chain in developed electricity markets will be turned upside down within the next 10–20 years, driven by solar and batteries.”*
- *“By 2025, everybody will be able to produce and store power. And it will be green and cost competitive, i.e., not more expensive or even cheaper than buying power from utilities.”*
- *“We think large-scale power plants are the structural* losers from this trend…”

Citigroup, Energy Darwinism II
September 2014[10]

- *“…on our estimates, renewables with battery storage is due to reach grid parity in large parts of the world within 15 years, which is inside the typical 30–35-year economic lifecycle of utility assets…We expect centralised power generation (coal, gas, nuclear and lignite plants) to be the first to feel the effects.”*
- *“We see winners (i.e., regulated utilities who will earn a fair return on what they spend including transmission and distribution wires related expenditures, which will increase as more renewables are built) and losers (i.e., certain unregulated/hybrid utilities whose outlook is predicated primarily on the economic dispatch of power generating assets).”*

RISK WITH REWARD: GRID-CONNECTED SOLAR-PLUS-BATTERY SYSTEMS OFFER OPPORTUNITY

Yet within this solar-plus-battery risk is also a great opportunity. Compared to the off-grid systems analyzed in The Economics of Grid Defection, optimally sized, grid-connected solar-plus-battery systems can reach economic parity sooner, and across more geographies, with faster customer adoption, and greater system benefits. This will herald a marked shift in the relationship between customers and utilities, and between customers and the grid. But since such systems will remain grid connected, they can offer value to that grid, rather than be seen solely as load defection from it.

RECENT TRENDS: DECLINING COSTS ARE EXPANDING CUSTOMER OPTIONS

Customer adoption of distributed solar and storage technologies has been growing, while costs for those technologies have been declining steeply. For example, residential rooftop solar’s installed cost per watt fell from $8.2 in 2009 to ~$4.5 through the first half of 2014, a 45% decline.[11] Meanwhile, U.S. installed solar PV capacity (MW/year) grew 1,066% over that same period, including 1,350% among residential solar.[12,13] Battery energy storage, including the lithium-ion chemistries focused on in this report, is on a similar trajectory,[14,15,16] though less mature than those of the solar industry. Batteries are on the cusp of accelerating cost declines driven by: 1) electric vehicle and consumer electronics adoption,[17,18] and 2) a growing storage market addressing demand charge reductions and California’s energy storage mandate.

FIGURE 13:
SOLAR PV U.S. ANNUAL INSTALLED CAPACITY
HISTORICAL AND NEAR-TERM FORECAST

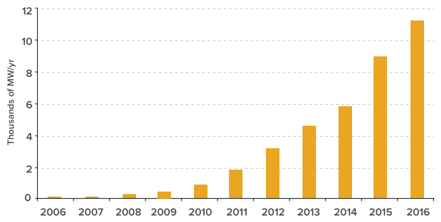
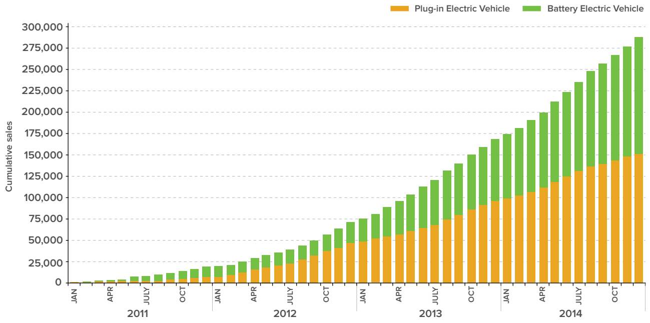


FIGURE 14:
U.S. CUMULATIVE SALES OF PLUG-IN ELECTRIC VEHICLES



While these cost declines are important, actual customer adoption will depend on many additional factors beyond pure economics,[19] such as a) relative hassle factor, b) available financing, c) valuing grid services provided so that customers on one side of the meter and utilities and grid operators on the other both see an expanded value proposition for such systems, d) customer demand for enhanced resilience, reliability, and other quasi-externalities, and e) future regulatory and rate structures that open, close, or expand market participation for solar-plus-battery systems and which either embrace customers that install these technologies or drive them away.

However, even low levels of adoption can have disruptive impacts on the financial health of utilities.[20]

FIGURE 15:
HISTORICAL SOLAR PV INSTALLED COSTS

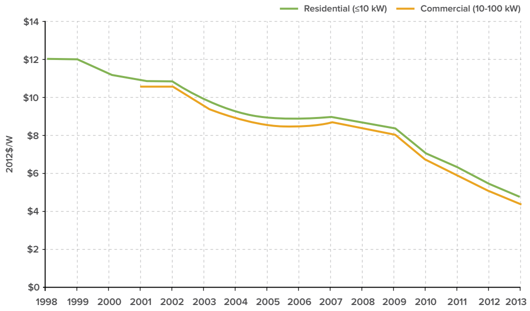
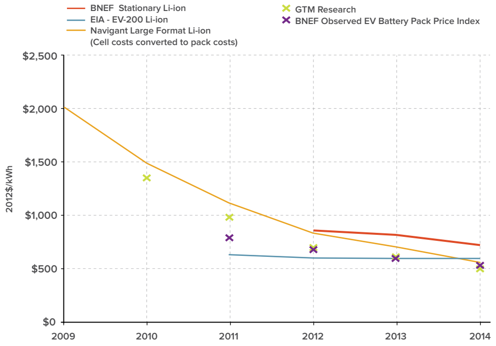


FIGURE 16:
LITHIUM-ION BATTERY PACK PRICES: HISTORICAL



In countries such as Germany—where customer-sited renewables adoption is ahead of the U.S.—utilities have seen their finances erode. Between 2008 and late 2013, European utilities lost a half-trillion euros off their market cap.[21] And major utilities E.ON and RWE have shed their financially-strained central thermal power plant business units to focus on grid operation and integration of distributed renewables.[22,23]

On the other hand, distributed energy resources such as rooftop solar and batteries can also have *positive* financial impact on utilities. For example, New York utility ConEd is looking at customer-sited DERs as a cost-effective alternative to a $1 billion power substation upgrade in its Brooklyn/Queens Demand Management effort.[24]

SECONDARY DRIVERS OFFER ADDITIONAL VALUE BEYOND CHEAPER KILOWATT-HOURS

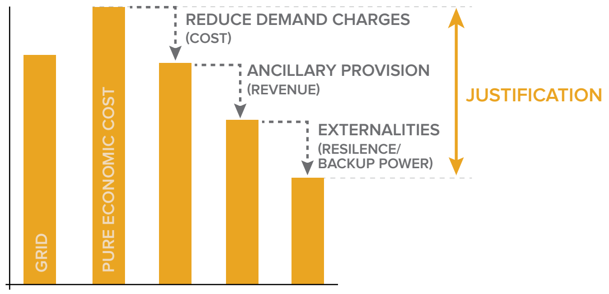
There are a few places where customers are investing in these solar-plus-battery systems for their per kWh energy charge savings alone, displacing pricier grid-purchased electricity with cheaper power produced with on-site solar-plus-battery systems. Most notably, Hawaii—where retail electricity prices are the highest of any U.S. state—has seen a flurry of customers investing in these systems.

But customers, utilities, and third-party developers may find reasons beyond simple economic parity to invest in solar-plus-battery systems, including decreased carbon intensity, improved resilience, mitigated or avoided impact of future potential rate increases, ancillary services provision (e.g., frequency and voltage regulation), deferral of distribution system upgrades, reduction in peak power usage, and power quality management (see Figure 17).

In places where these additional value streams are sufficiently large and the market environment allows them to be monetized, solar-plus-battery systems can have net positive value today—even if their basic levelized cost of energy is still more expensive than retail electricity from the grid—and hence are making market inroads among early adopters.[25] For example, storage systems are providing demand-charge reduction in California, resilience in the Northeast, and remote-infrastructure support in off-grid applications (e.g., cell towers).[a]

In fact, several companies—including Sunverge, Sunpower, and SolarCity/Tesla—are actively commercializing solar-plus-battery technology combinations with a variety of business models.[26] Most such business models focus on using solar-plus-battery systems to either decrease customer costs (e.g., cheaper per-kWh price for generation, lower demand charges) or increase customer revenue (e.g., compensation for services provided to the grid), or both. With a recent influx of market participants, ranging from startups to established industry titans, and other companies declaring their intent to enter the solar-plus-battery market, mounting momentum of players moving into this solution space suggests that the market opportunity for solar-plus-battery solutions has expanded, and will likely only continue to do so as component costs decline.

FIGURE 17:
SECONDARY CUSTOMER VALUES BEYOND BASIC ECONOMICS



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[a] See, for example, the Konterra solar-battery microgrid in Laurel, MD, built by Solar Grid Storage with a 402 kW solar PV array sized to meet 20% of annual need and grid-interactive battery energy storage earning revenue from ancillary services in the PJM market. In San Francisco, Stem and CODA deployed distributed battery storage systems with energy optimization software for Intercontinental Hotels, helping reduce demand charges at facilities.

FIGURE 18:
GRID RELATIONSHIP SPECTRUM

On-grid/ Conventional Customer	Grid-tied/ Solar Customer	Grid-tied/ Solar + Battery Customer	Off-grid/ Solar + Battery Customer

← CUSTOMER RELATIONSHIP WITH THE GRID →

GRID DEPENDENT — GRID INDEPENDENT

CUSTOMERS' RELATIONSHIP WITH THE GRID IS EVOLVING

It remains unlikely that large numbers of customers would leap directly from grid connected to grid defected. Instead, a far more likely—and thus potentially even more disruptive—scenario is incremental customer investment in first solar-only and then solar-plus-battery grid-connected systems. This would lead to increasing levels of load defection, including among current grid-connected rooftop solar customers who "enhance" their solar PV with the addition of battery energy storage.

With greater awareness of how this transition might occur, customers will be in a better position to make decisions and investments that can lower their electricity bills and improve the quality of their service. In addition, our analyses can provide insights for entrepreneurs to grow businesses in new markets. At the same time, we hope to provide guidance to utilities and regulators who are 1) poised to send better price signals to guide and motivate a more-efficient evolution of the electric grid, 2) lead the creation of new business models both for utilities and customers, and 3) begin forging a new regulatory construct.

ABOUT THIS ANALYSIS: UNDERSTANDING THE EVOLUTION

This report explores how grid-connected solar-plus-battery system configurations and economics would evolve over time, and what magnitude of customers and load that could represent. 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 in meeting 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?

This analysis is evaluated from a customer-facing economics perspective but also considers the implications for utilities and regulators.

ASSUMPTIONS AND METHODOLOGY

02

ASSUMPTIONS AND METHODOLOGY

For parallelism and ease of comparison, we began this analysis with the same inputs and assumptions as *The Economics of Grid Defection*, held constant in most cases and updated where appropriate. A complete list of modeling assumptions, inputs, and results can be found in appendices A–F.

TIMELINE

We modeled present day (2014/15) through 2050 in 2012$, just beyond the 30-year cost recovery period of rate-based utility investments that would be made today.

GEOGRAPHY

Our analysis focused on five locations through the United States, considering both residential and commercial customers in each locale:

- Honolulu, Hawaii
- Los Angeles County, California
- San Antonio, Texas
- Louisville, Kentucky
- Westchester County, New York (within the New York City metropolitan area)

We chose these locations because they cover a representative range of factors that influence solar-plus-battery system economics and operation, including annual solar resource potential, retail electricity prices, and quantity of currently installed solar PV[27] (see Table 1).

CUSTOMER CONSIDERATIONS: LOAD PROFILES AND SYSTEM SIZE LIMITATIONS

Modeled Load Profiles

We modeled both commercial and residential median load profiles specific to the regional climate for each of the five locations. For the commercial load profiles, we considered a generic ~43,000-square-foot, 4-story hotel. For the residential load profiles, we considered a ~2,500-square-foot detached single-family home.

Solar-Plus-Battery System Size Limitations and Configuration

We allowed system size and configuration to vary as economics dictated, making some modest constraints to account for the likely physical space limitations of residential customers. We modeled three primary system configurations: 1) grid only, 2) grid-plus-solar, and 3) grid-plus-solar-plus-battery. In all cases, system configuration (including size) and portion of load served by that system (grid vs. solar) optimized to find the lowest customer-facing cost.

TABLE 1: PROFILES OF GEOGRAPHIES

	WESTCHESTER, NY	LOUISVILLE, KY	SAN ANTONIO, TX	LOS ANGELES, CA	HONOLULU, HI
INSOLATION (kWh/m^2/day)	4.5 kWh	4.5 kWh	6 kWh	6 kWh	5.5 kWh
2014 AVG RETAIL PRICE ($/kWh)	$0.17–$0.23	$0.08–$0.09	$0.06–$0.10	$0.11–$0.18	$0.36–$0.42
INSTALLED PV BY STATE (MW)	140 MW	3 MW	200 MW	1,900 MW	27 MW
MARKET STRUCTURE	Restructured	Regulated	Restructured	Restructured	Regulated

SOLAR-PLUS-BATTERY SYSTEM COSTS

Our modeled forecasts for solar-plus-battery system costs used averaged projections from a variety of datasets developed through a thorough literature review for solar PV[28,29,30,31,32,33,34,35] and batteries.[36,37,38,39,40] Since capital costs are the predominant component of customer-facing costs, we used National Renewable Energy Laboratory-derived[41] capital costs for both residential and commercial systems. In general, forecasts in this report largely reflect those previously used in *The Economics of Grid Defection*. However, in the time since that report's release in February 2014, new price points for both solar and storage have emerged that are proving less expensive, and in the case of storage, substantially so, than our averaged forecast.[42] As an added conservatism, we did not adjust our analysis based on these data points.

FIGURE 19:

SOLAR PV INSTALLED COSTS: FORECASTED

RESIDENTIAL

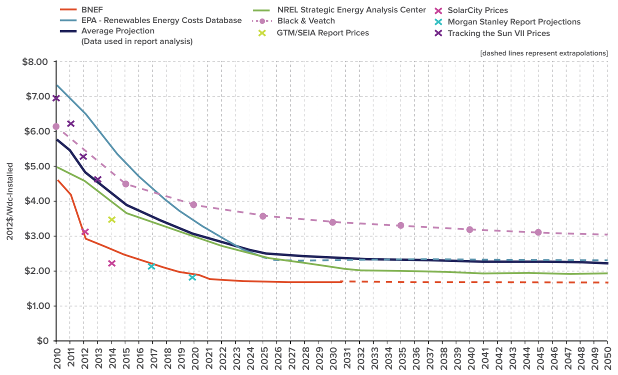


FIGURE 20:

INSTALLED PV COSTS: FORECASTED

COMMERCIAL

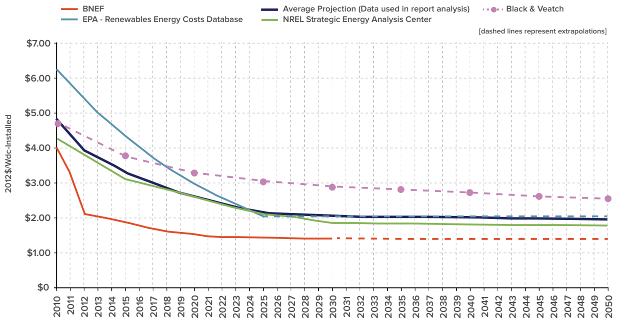
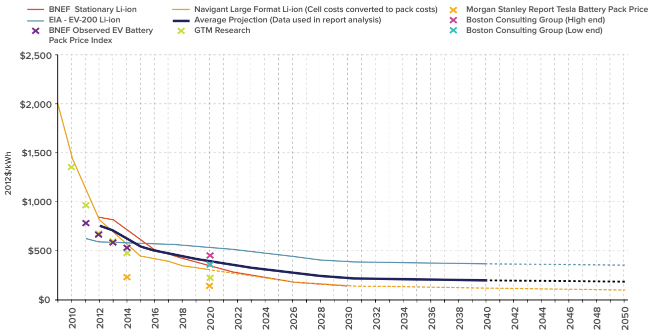


FIGURE 21:

LITHIUM-ION BATTERY PACK PRICES: HISTORICAL AND FORECASTED



RETAIL GRID ELECTRICITY PRICES

We projected utility retail electricity prices assuming no change to current pricing models and rate structures.[b] We used an annual price increase of 3%-real (i.e., inflation adjusted) based on recent price trends from U.S. Energy Information Administration data. During the period 2004–2012, commercial and residential retail real prices annually rose an average 2.7% and 2.8%, respectively, for the geographies we studied (see Figures 22 and 23).[c] With an aging grid requiring up to $2 trillion in investment through 2030[43] to maintain, replace, and/or upgrade infrastructure, some regions in the U.S. have more recently been seeing real retail electricity price increases in excess of 3%.[44,45] Until such trends change, a national average 3%-real per year price increase should represent a reasonable estimate for our analysis.

FIGURE 22:

AVERAGE RETAIL ELECTRIC PRICES

RESIDENTIAL - HISTORICAL AND 3% FORECAST FOR STUDY GEOGRAPHIES (NY, KY, TX, CA, HI)

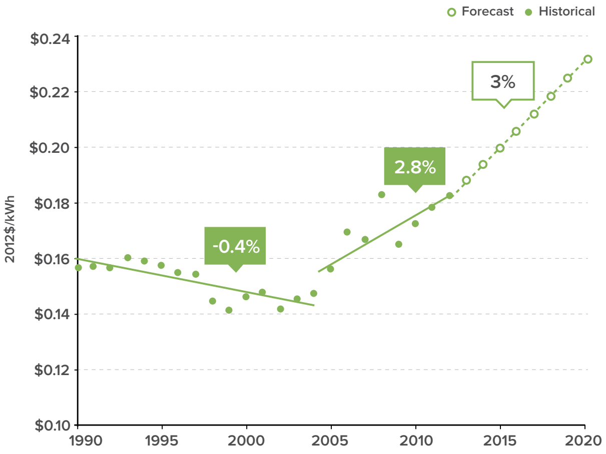
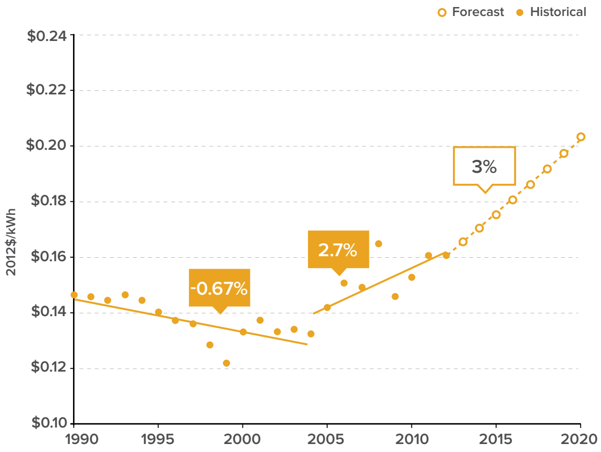


FIGURE 23:

AVERAGE RETAIL ELECTRIC PRICES

COMMERCIAL - HISTORICAL AND 3% FORECAST FOR STUDY GEOGRAPHIES (NY, KY, TX, CA, HI)



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[b] Commonly, current rate structures are designed to support cost of service utility regulation. While several utilities and regulatory bodies across the U.S. have begun to experiment with alternate rate structures and cost recovery models, these remain the exception and not the norm. In our projections of future retail costs, we assumed there would be no changes to current rate structures or cost recovery models for utilities.

[c] We are using the same data as in *The Economics of Grid Defection* to maintain continuity. As of late February 2015, updated EIA average price by state provider data was released, which included 2013 data. Those updated numbers yield 2005–2013 growth rates of 2.2% and 2.6% for the commercial and residential retail rates, respectively.

RETAIL RATE STRUCTURES

When modeling the economics of grid-connected solar-plus-battery systems relative to retail electricity from a utility, the retail rate *structure* is nearly as important as the magnitude of the rate. Whether a customer pays a pure volumetric price, has net energy metering, time-of-use pricing, demand charges, fixed charges, or other rate structures has an enormous influence on the economics. For our core analysis, we modeled the rate structures that cover the overwhelming majority of customers nationwide in each class:

- Residential customers: volumetric pricing ($/kWh)[d]
- Commercial customers: three-part pricing, which includes a volumetric component ($/kWh), a monthly demand charge based on highest power load ($/kW), and a monthly fixed charge ($).

To develop geographic-specific prices for our analysis, we referenced tariff sheets compiled by the Genability rates database,[46] which we than escalated at 3%-real annually (see Table 2).

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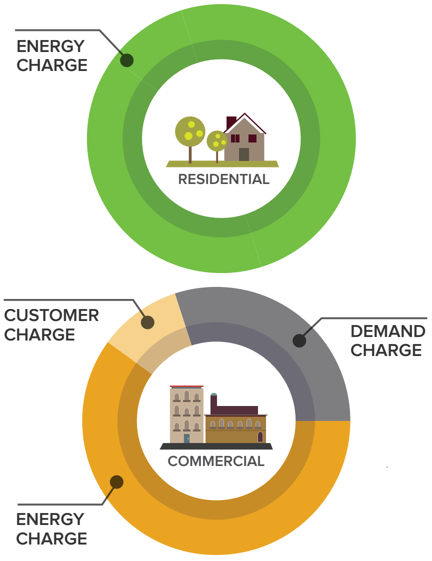
[d] Residential fixed charges, which are a much smaller portion of the customer's total bill than in commercial rates, were not considered, for simplicity.

FIGURE 24:
RETAIL RATE STRUCTURES



ENERGY CHARGE
kWh-based generation costs (e.g., fuel, wholesale electricity)

CUSTOMER CHARGE
Flat, monthly charge covering fixed costs of servicing customer regardless of use (e.g., billing, customer service)

DEMAND CHARGE
Costs of the generation, transmission, and distribution capacity to serve peak demand

TABLE 2: UTILITY RATES USED IN MODELING

2012 COMMERCIAL RATES								
			Escalation	WESTCHESTER, NY	LOUISVILLE,KY	SAN ANTONIO, TX	LOS ANGELES, CA	HONOLULU, HI
Actual Rate	Consumption ($/kWh)	Winter	3% real	$0.11	$0.04	$0.06	$0.06	$0.37
		Summer				$0.07	$0.08	
	Demand ($/kW/month)	Winter	3% real	$19.10	$12.49	N/A	$6.68	$10.22
		Summer		$24.14	$12.50		$23.39	
	Fixed (monthly)	Winter	3% real	$110.29	$201.83	$8.25	$123.31	$38.00
		Summer		$139.96				
	Timeline	Winter		Oct.–May	Oct.–Apr.	Oct.–May	Oct.–May	N/A
		Summer		Jun.–Sep.	May–Sep.	Jun.–Sep.	Jun.–Sep.	

2012 RESIDENTIAL RATES						
Volumetric	3% real	$0.21	$0.09	$0.09	$0.17	$0.34

EXCESS ELECTRICITY

Behind-the-meter systems

The rate structures we used in our analysis did not value the grid services that batteries could provide, such as contingency reserves and voltage and frequency regulation, which would further improve their economics. Nor did we value any export—not even avoided fuel costs. *All solar-only and solar-plus-battery systems were modeled as largely self-consuming with no export compensation (i.e., optimized for behind-the-meter operation).* This analysis focuses on customer cost (i.e., levelized cost equivalent for electric services) and not potential revenue to the customer.

Net Metering Treatment

Under net energy metering (NEM), customers receive credit at the retail rate for energy exported to the grid. Although NEM is a prevalent policy found in most U.S. states, we considered it inappropriate to include in our baseline analysis. Traditional regulatory and utility business model paradigms have involved the one-way flow of electrons across the meter from the grid to the customer. In that paradigm, DERs, when deployed, are about behind-the-meter value that accrues to the customer (e.g., self-consuming solar PV, batteries for backup power and demand charge reductions). Net energy metering represents just one of several newer policies (e.g., value-of-solar tariffs, feed-in tariffs, avoided fuel cost compensation) that compensate *two-way* flow of electrons across the meter.

Thus although export compensation via bill credits or direct payments 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. However, we do treat net metering as a special case later in the report.

MODELING SOFTWARE

We used the HOMER® hybrid optimization modeling software to find the lowest-cost electric system to meet electrical demand, ranking simulated systems by net present cost (NPC), which accounts for all of the discounted operating costs over the system's lifetime. We used the HOMER model to determine the levelized cost of energy (LCOE), solar-plus-battery component sizes, and grid needs for each location.

EXTERNALITIES

We did not consider several variables that could meaningfully *improve* the customer-facing economics presented in our analysis:

- ***Incentives:*** We did not consider state-level incentives or the extension of federal incentives beyond their current expiration date.
- ***Export compensation or alternate use of excess generation:*** We did not assign any value to excess electricity production, although most locations currently have some form of compensation for electricity exported to the grid. Additionally, use of excess generation for water heating or other thermal applications could improve the system economics, but were also not considered.
- ***Accelerated technology cost declines, lower interest rates, or integrated investments in efficiency and flexibility:*** Any of these factors could improve the economics of these systems.[e]
- ***Secondary values:*** We assigned no value to attributes of solar-plus-battery systems beyond direct bill savings (e.g., the potential value of reliability, ancillary services, or carbon reduction).

We also did not consider several variables that could meaningfully *worsen* the customer-facing economics presented in our analysis:

- ***Opportunity costs:*** We do not account for any penalty a customer might place on solar-plus-storage as a result of locking in an energy source for a period of years.
- ***Changes to rate structures or decreases in overall utility cost structure:*** We extrapolate current pricing and overall bill increases for customers. Fundamental changes to pricing or breakthroughs that reverse current utility cost trends would weaken the investment thesis for solar-plus-battery systems. For example, the addition of fixed charges for residential customers—as some utilities have proposed—would retard the economics substantially in the near term, but might hasten defection in the longer term.

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[e] In our earlier report, we ran alternative scenarios to understand the effect of these factors and saw dramatic acceleration of parity for grid defection. We would expect a similar effect for this analysis.


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RESULTS

03

RESULTS

Our analysis yields several striking findings that will have important implications for regulators, utilities, DER developers, and customers. In general, grid-connected self-consuming solar will become economic for nearly all customers imminently, with grid-connected solar-plus-battery systems following soon after, much faster than the off-grid solar-plus-battery systems we modeled in *The Economics of Grid Defection*. These grid-connected systems will eventually cover the vast majority of customer load. This load defection will essentially relegate the grid to a backup-power-only role for customers that adopt these systems.

In greater detail, our key findings are:

Solar-plus-Battery Systems Rapidly Become Cost Effective

Distributed solar first and then solar-plus-battery systems covering only a portion of a customer's load will have compelling economics without the support of incentives or feed-in compensation in many important markets within 15 years.

The economically optimal system configuration evolves over time, from grid only in the near term, to grid-plus-solar, to grid-plus-solar-plus-batteries in the longer term. While many customers in many geographies already have economic solar with net energy metering, we found that smaller (e.g., 1–2 kW for residential customers), non-exporting solar PV systems that do not rely on net energy metering *will become economic for all customers in all geographies we studied within the next decade.*

FIGURE 25:
ECONOMICALLY OPTIMAL SYSTEM CONFIGURATION
RESIDENTIAL

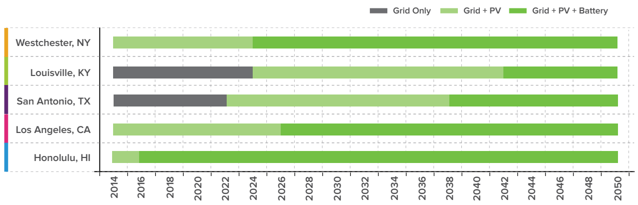
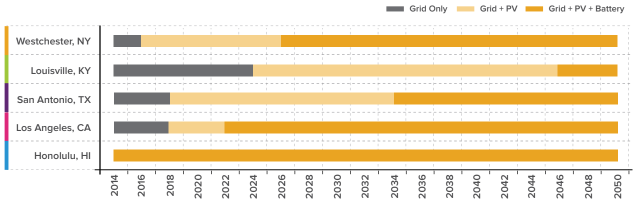


FIGURE 26:
ECONOMICALLY OPTIMAL SYSTEM CONFIGURATION
COMMERCIAL



In places like Honolulu, Hawaii, Los Angeles, California, and Westchester, New York, these systems are economic today. As grid retail prices increase further and distributed storage costs drop, new customers will find solar-plus-battery system configurations most economic in these three major markets within 12 years. 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.

A GEOGRAPHY IN DETAIL: WESTCHESTER COUNTY, NY

For commercial and residential customers in Westchester County, NY, the levelized cost of energy (LCOE) equivalent for grid-supplied electricity starts today at $0.19 and $0.21, respectively, escalating at our forecasted 3%-real in the years ahead. Within just a handful of years, small, non-exporting solar PV becomes economic to serve a portion of load as retail grid electricity prices continue to rise. By 2030, it makes even more compelling economic sense for customers to invest in grid-connected solar-plus-battery systems, which significantly reduce a customer's LCOE costs relative to grid-only electricity.

FIGURE 27:
ELECTRICITY COST OF SUPPLY
RESIDENTIAL - WESTCHESTER, NY

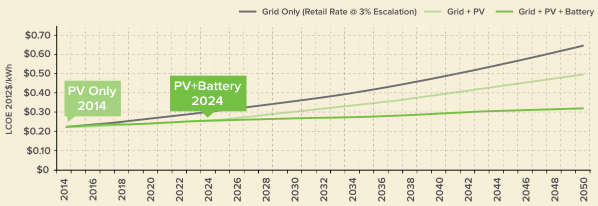
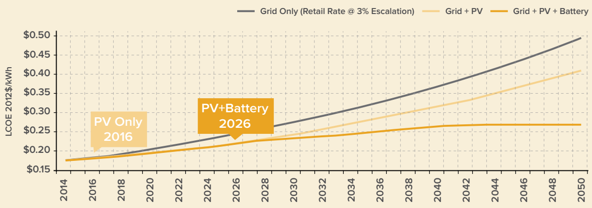


FIGURE 28:
ELECTRICITY COST OF SUPPLY
COMMERCIAL - WESTCHESTER, NY



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

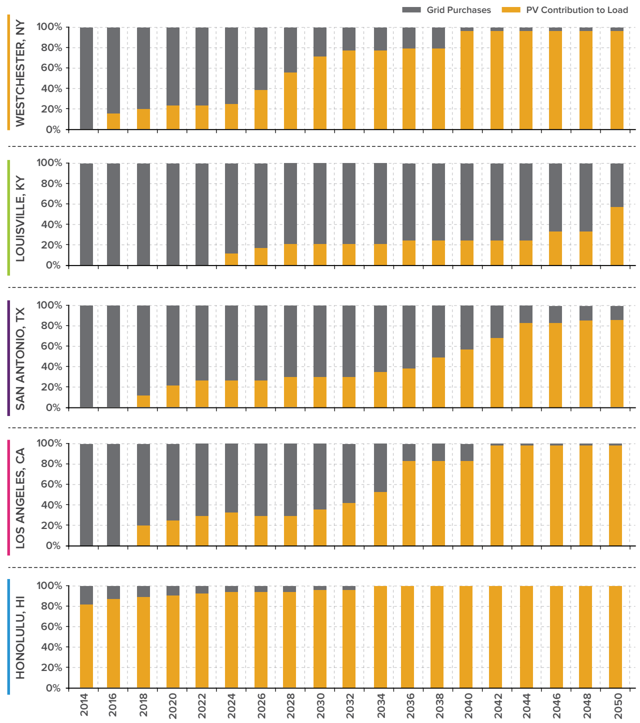
The relative costs and benefits of grid-connected solar-plus-battery systems suggest that significant load defection from the grid to these solar-plus-battery systems will be preferable before complete customer defection is economic.

Our analysis shows that the relative contributions of the grid and a customer's solar and solar-plus-battery systems to meet customer load 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 places such as NY, CA, and TX, our analysis shows the grid optimally supplying 80–100% of residential and commercial customers' load today but just 3–25% by around 2040. Reciprocally, solar PV grows from supplying little to no customer load to supplying a substantial majority to nearly all customer load over that same time period.

This evolution suggests that there is no "new normal," either for the grid or for solar-plus-battery systems. Solar and solar-plus-battery solutions—including their customer-sited deployment and grid integration—will need to be adaptive. The economically optimal solar-plus-battery system configuration, size, and load served will change over time, suggesting shifting patterns of customer and third-party investment. Meanwhile, customers who previously invested in one system configuration at an earlier date may similarly consider subsequent further incremental investment, such as to expand a solar PV array and/or add supplemental battery energy storage.

FIGURE 29:
ECONOMICALLY OPTIMAL GENERATION MIX
RESIDENTIAL

FIGURE 30:
ECONOMICALLY OPTIMAL GENERATION MIX
COMMERCIAL



A GEOGRAPHY IN DETAIL: WESCHESTER COUNTY, NY

For commercial and residential customers in Westchester County, NY, grid purchases dramatically decrease within 10–15 years (by 2025–2030) from a majority to a minority of customer load, and eventually decline to ~3% and 20%, respectively, by about 2040.

FIGURE 31:
ECONOMICALLY OPTIMAL GENERATION MIX
RESIDENTIAL - **WESTCHESTER., NY**

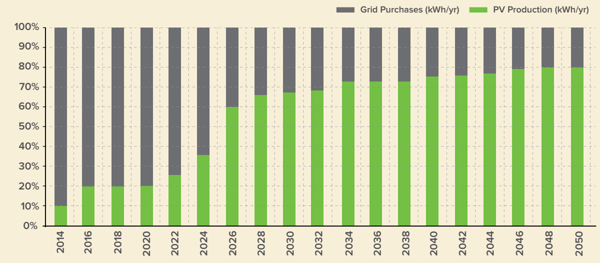
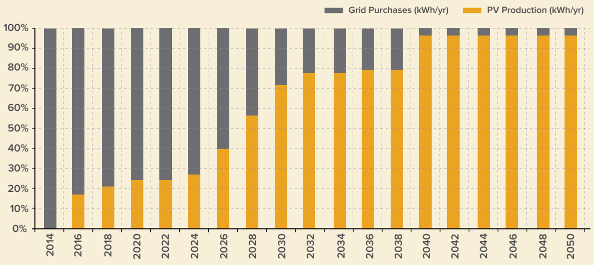


FIGURE 32:
ECONOMICALLY OPTIMAL GENERATION MIX
COMMERCIAL- **WESTCHESTER., NY**

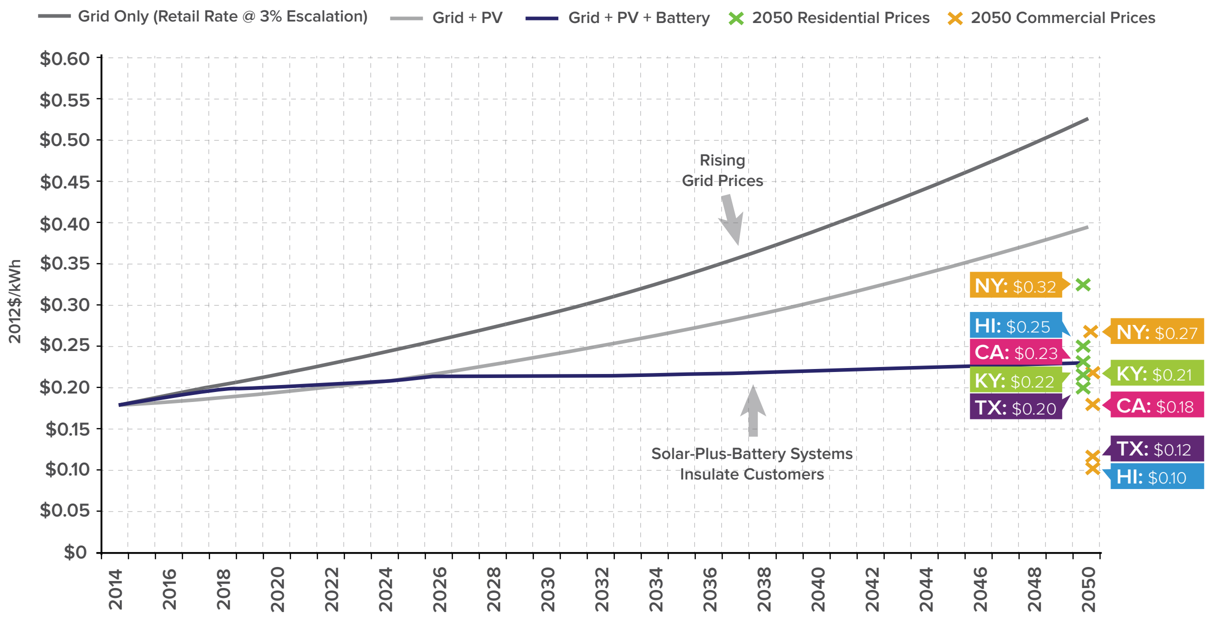


Peak Price for Individual Customers

The adoption of grid-connected solar-plus-battery systems will lead to lower and more stable prices for customers.

Regardless of how high retail electric prices climb in the future, investing in combinations of solar and batteries will enable individual customers to contain costs for electric service. The lowest-cost option for electric service can effectively cap customers' electricity costs for all scenarios we analyzed—about $0.10–$0.30 for commercial customers and $0.20–$0.35 for residential customers across the geographies—locking in pricing for a portion or all of their load and shielding them from future changes in rates. For example, for a median residential customer in Westchester County, NY, the average monthly electricity bill would reach $357 by 2030 and $645 by 2050 for grid electricity based on forecasts, while peak price through adding a solar-plus-battery system would be just $268 per month by 2030, leveling off around $317 per month by 2050. The specific price cap differs slightly by geography, but all geographies exhibited this same trend. Importantly, though, this "peak price" finding holds only for electric service for individual customers who invest in solar and solar-plus-battery systems. System-wide, 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 33:
PEAK PRICE



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

As grid-connected solar-plus-battery systems become economic for large numbers of customers, and as those systems supply greater and greater portions of customers' load, the magnitude of potential load defection from the grid is large, with significant potential impacts on revenue from energy sales and cost recovery for major and necessary grid investments.

Between 2010 and 2030, the grid will require up to an estimated $2 trillion in investment, or about $100 billion per year.[47] Those costs will need to be recovered through revenue from energy sales. If even a small fraction of the electricity load supporting that investment and revenue goes away, it will likely have a large impact. To examine a more comprehensive cross-section of customer economics and the magnitude of possible load defection, we looked at the Northeast U.S. more broadly (i.e., PA, NJ, NY, CT, MA, and RI) to see the maximum possible load defection the grid could see based on customer adoption following the optimal economics of our analysis.[f] (It will be up to the reader to decide what level of customer adoption is realistic. Our estimate represents an upper boundary to quantify the magnitude of the load defection at stake.)

In the Northeast U.S. alone, as early as 2020—just five short years away—customer load defection makes meaningful inroads to utility annual energy sales (~10–20%). By 2030, load defection rises substantially (to ~50–60%). And by 2050, maximum possible load defection reaches most of utility annual energy sales (~80–97%).

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[f] We used 2012 utility sales data from the U.S. Energy Information Administration (EIA) to identify the total number of residential and commercial MWhs sold by utilities in the region, including the decile distribution (i.e., tenths) between the most expensive and least expensive MWhs. We then compared customers' lowest-cost option for grid-connected solar and solar-plus-battery systems to the range of utility retail per-kWh prices to determine what percentage of customers would be "in the money" with DERs throughout the region. Lastly, we multiplied the MWhs of customers who'd be in the money by the optimal portion of load served by solar and solar-plus-battery systems and the per-MWh cost for those deciles. This yielded, in MWh and 2012$, the maximum possible load defection the grid could see based on the economics of our analysis.

TABLE 3:
POTENTIAL MAGNITUDE OF UTILITY LOAD DEFECTION

RESIDENTIAL				
	MWh	% kWh Sales	# Customers	2012$ (Annual)
2020	3.5 million	10%	1.9 million	$684 million
2030	58 million	50%	9.6 million	$15.4 billion
2050	139 million	80%	20.7 million	$65.8 billion

COMMERCIAL				
	MWh	% kWh Sales	# Customers	2012$ (Annual)
2020	9 million	20%	500,000+	$1.6 billion
2030	83 million	60%	1.9 million	$19.4 billion
2050	186 million	97%	2.9 million	$78.4 billion

FIGURE 34:
NORTHEAST LOWEST-COST OPTION VS. GRID PRICE RANGE
RESIDENTIAL

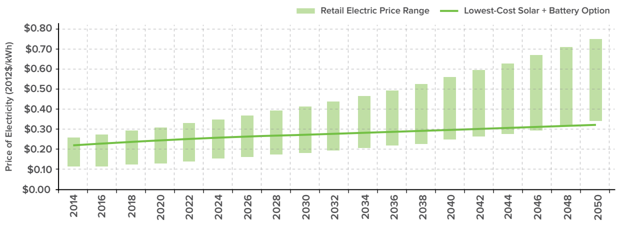


FIGURE 37:
NORTHEAST LOWEST-COST OPTION VS. GRID PRICE RANGE
COMMERCIAL

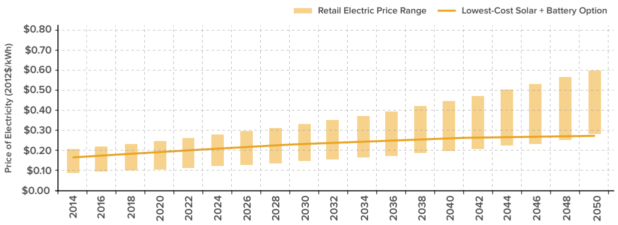


FIGURE 35:
NORTHEAST POTENTIAL CUSTOMER DEFECTION
RESIDENTIAL

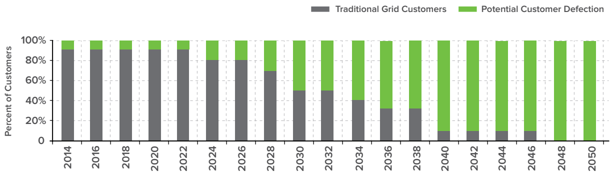


FIGURE 38:
NORTHEAST POTENTIAL CUSTOMER DEFECTION
COMMERCIAL

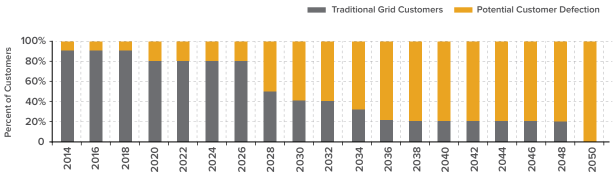


FIGURE 36:
NORTHEAST POTENTIAL LOAD DEFECTION
RESIDENTIAL

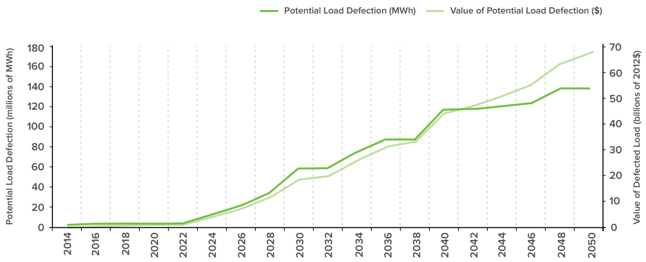
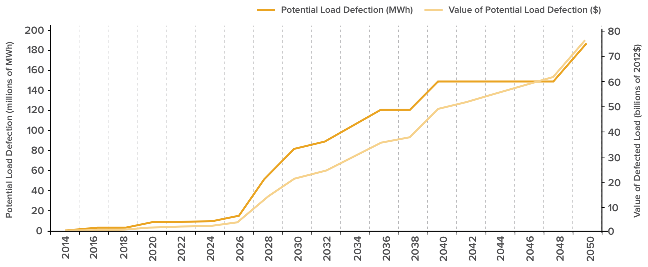


FIGURE 39:
NORTHEAST POTENTIAL LOAD DEFECTION
COMMERCIAL



Initially, grid-connected solar and solar-plus-battery systems are “in the money” compared to the more-expensive grid MWh throughout the Northeast region. But over time, grid-connected solar-plus-battery systems become more cost effective than even the cheapest grid prices across the region. As more and more customers find grid-connected solar-plus-battery systems their most economic option, potential customer adoption based on optimal economics encompasses all customers. As those customers’ systems supply greater and greater portions of their load, the defection—in MWh and 2012$—grows substantially.

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

Net energy metering is a contentious yet prevalent policy that has successfully supported distributed solar PV's growth in the U.S. The debate about its future is one of the most politically and emotionally charged topics in the electricity industry today. We found ourselves in the middle of a similar debate—to model the economics of grid-connected solar and solar-plus-battery systems with or without net metering. Finding convincing reasons for each case, we decided to study both.

Importantly, valuation for excess solar generation is not a binary option. "With net metering" and "without net metering" are only two options along a spectrum of valuation techniques we can offer customers with distributed generation. But for the purpose of this research, these two options presented the most practical bookends to define the realm of possibilities.

In modeling grid-connected solar-plus-battery systems with and without net energy metering, we found notable differences in gross and net grid purchases, system configurations, and total system electricity production. The results for commercial and residential systems were very similar for all geographies.

Our examination of Westchester County, NY, is illustrative. We found:

- *Load defection happens almost immediately and entirely for customers with net energy metering.* Customers today in areas that allow net metering typically purchase or lease a solar PV system that meets 100% of their total load. While net grid purchases also decline for non-exporting customers, the decline is far more gradual. However, the ultimate outcome is similar with substantial load defection—non-exporting commercial customers' grid purchases shrink to near zero eventually; residential customers' grid purchase decline is not as severe, but still tapers to only ~20% of load.[g]
- *Net energy metering removes almost all incentive to add a battery to a solar system.* For both commercial and residential customers, when NEM was available, adding a battery to the system was never the most economical option for the customer. Customers might still choose to invest in a battery if secondary values such as resilience (i.e., backup power) are important, or if they are charged a capacity-based fee for grid usage.
- *Systems with and without NEM use the grid very differently.* Though net-metered systems almost immediately decline to zero net grid purchases, gross grid purchases remain. Net-metered solar-only systems effectively use the grid daily like a battery, exporting surplus generation during day and buying back electricity at night when solar PV isn't producing. On the other hand, for self-consuming solar and solar-plus-battery systems, net and gross grid purchases are the same by definition and decline significantly. With the grid serving an infrequent but important backup role for these systems, important questions remain about implications for needed grid capacity and other considerations.

Though we didn't specifically model other scenarios, our quantitative findings with NEM are useful for qualitatively considering other possibilities, such as recent proposals to introduce more significant residential fixed charges to utility customers' bills. 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.

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[g] For example, a 6 kW system is enough to meet 100% of a typical 3-bedroom home in Denver, CO, right in the middle of the typical installed range (Tracking the Sun VII).

Regardless, these considerations highlight the importance of rate structures—both on our analysis and on the likely economics and timing of customer behavior, including DER adoption.

FIGURE 40:

NET GRID PURCHASES WITH AND WITHOUT NET METERING

RESIDENTIAL

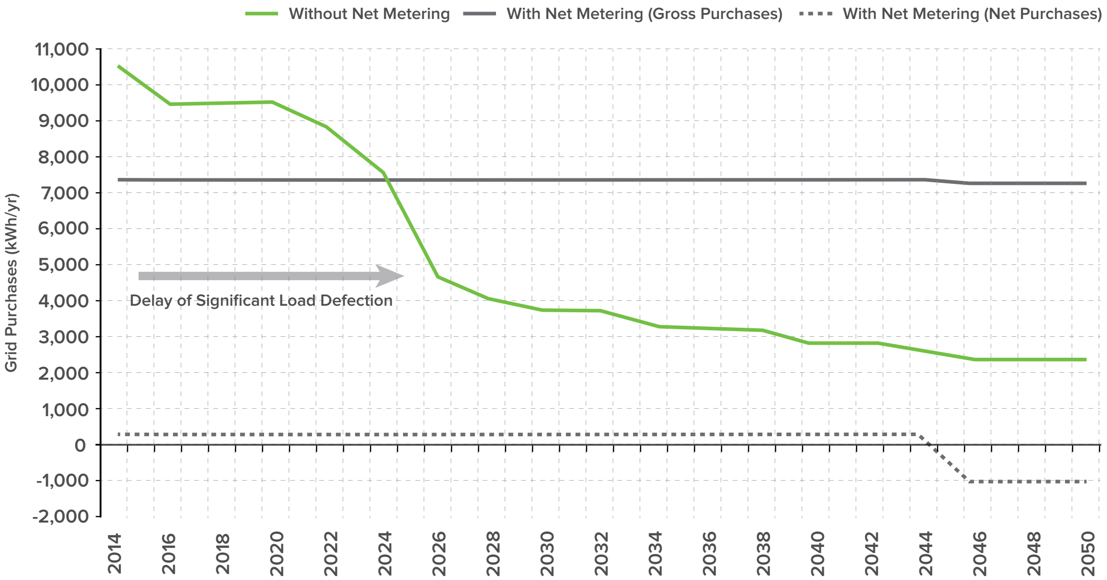
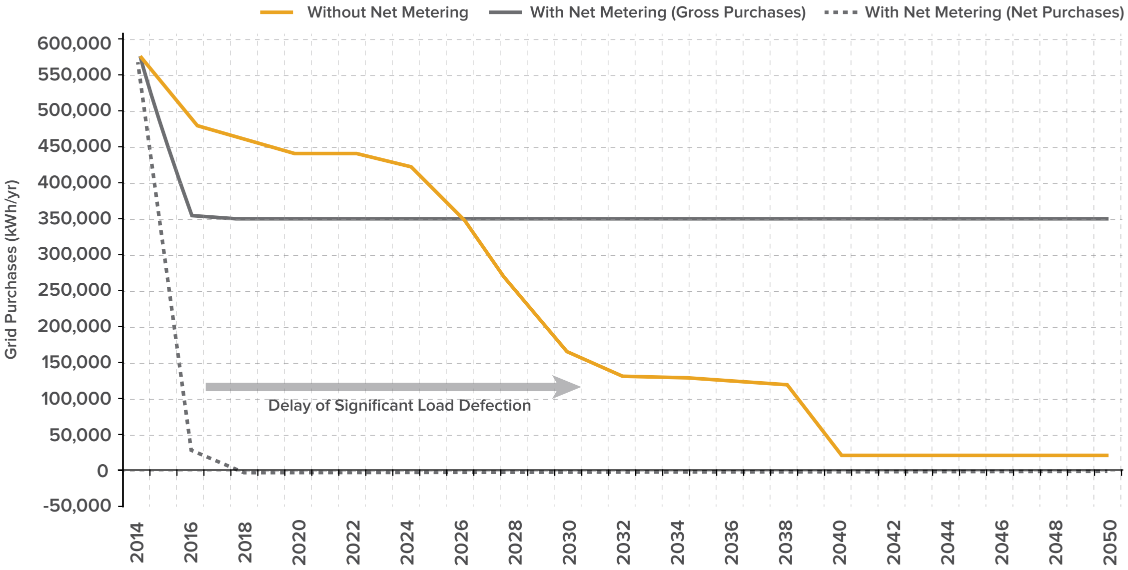


FIGURE 41:

NET GRID PURCHASES WITH AND WITHOUT NET METERING

COMMERCIAL



THE INFLUENCE OF RATE STRUCTURES ON SOLAR-PLUS-BATTERY SYSTEM ECONIMICS

While future rate structures might look different from those we see today, we can test the potential impact of different types of rates on the economics of solar-plus-battery systems. We considered two variations on today's three-part commercial rate by shifting it to one of two extremes while keeping total utility revenue equal in all variations.

1. Fixed rate: a customer pays the same monthly fee for grid connection and grid power regardless of use of electricity (i.e., there are no demand or volumetric usage fees).
2. Volumetric rate: a customer pays only for kWhs used, regardless of pattern of use (i.e., there are no demand or fixed fees).

TABLE 4:
INFLUENCE OF RATE STRUCTURE ON SOLAR-PLUS-BATTERY ECONOMICS

	FIXED	CURRENT	VOLUMETRIC
Structure of potential rate	Single fee for use ($/month)	three-part rate ($/kWh, $/kW, $/month)	Priced per consumption ($/kWh)
Timing of parity for grid-connected solar-plus-storage systems	Up to 15 years later (coincident with timeline for grid defection)	*The Economics of Load Defection* Reference Case	Up to 7 years earlier
Likely customer behavior	Defer DER investment until off-grid parity point, and then defect	Invest to reduce both demand charges and total energy purchases	Investment in successively larger systems to continually lower electric cost
System profile	A completely off-grid system oversized to meet full customer load	Balanced investment between distributed generation and load-shaping (through batteries) to reduce demand charges	Solar-focused system to reduce grid purchases; no investment in improvements to load shape

Thus, rate structures can dramatically impact the timing by which solar-plus-battery systems become economic, the optimal configuration of those systems, and how such systems are used in concert with (or in the absence of) the grid.

- A fixed rate has the benefit of stable revenues, but can push customers to defect from the grid without any intermediate steps when rates become more expensive than solar-plus-battery systems.
- A volumetric rate encourages customers to invest in efficiency and distributed generation, but can lead to unpredictable or peaky use of grid resources.

While here we only looked at the potential impact of two shifts within the conventional three-part commercial rate structure, a much wider variety of rate structures will in practice influence customer behavior. It will be important to try to link this customer behavior back to its potential impact on system-level costs.

IMPLICATIONS AND CONCLUSION

04

IMPLICATIONS AND CONCLUSION

BEYOND CUSTOMER SAVINGS: HOW GRID-CONNECTED SYSTEMS CAN BENEFIT THE GRID

There will always be specific applications where foregoing a grid connection will make sense (e.g., remote communities or industrial operations), in most instances, building completely off-grid solar-plus-battery systems will leave excess capital on both sides of the meter. Off-grid systems need to be oversized to guarantee stand-alone reliable service, while utilities' load loss from customer defection leaves central thermal generation capacity with smaller remaining load to serve. Similarly, failing to accurately represent the value of distributed resources can lead to excess and inefficient investment on both sides of the meter.

And although our findings show that utilities' load 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 not just to individual customers but also back to the grid and society*, especially if those value flows are monetized with new rate structures, business models, and regulatory frameworks.

A FORK IN THE ROAD FOR THE ELECTRICITY SYSTEM

The electricity system is at a metaphorical fork in the road, where the deployment of solar-plus-battery systems—including their configuration, operation, and value to the grid and customers—will be greatly affected by utility and regulatory action (or inaction). More and more of the country will see grid parity for solar PV systems, even without export compensation such as net metering. Geographies where PV is already at grid parity will begin to see grid parity for solar-plus-battery systems that will allow large amounts of load to self-provide.

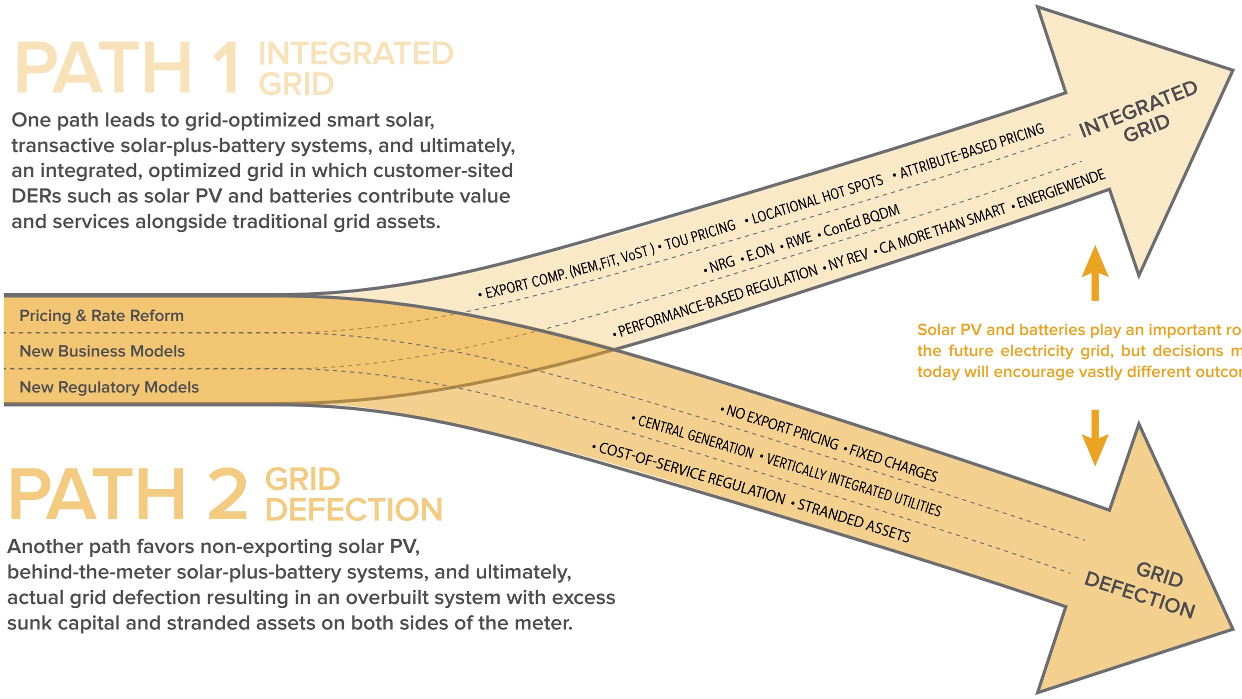
Decisions made in the short-term can set markets down extremely different paths articulated in Figure 42. Solar PV and batteries will have value along both paths and figure centrally in any future electricity grid, but their role and the nature of that future grid will vary depending on choices made today that establish trajectories with vastly different outcomes.

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 customer-side resources are likely overbuilt and existing and planned grid assets are 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 more-efficient deployment of capital and physical assets, with investments made in a way that supports the grid, providing an alternative to central generation and creating value in the distribution system through peak load management, ancillary services, congestion relief, and other services that support a more-connected, lower-cost electricity system.

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.

FIGURE 42:
POSSIBLE TRAJECTORIES FOR ELECTRICITY GRID EVOLUTION



PATH 1 INTEGRATED GRID

One path leads to grid-optimized smart solar, transactive solar-plus-battery systems, and ultimately, an integrated, optimized grid in which customer-sited DERs such as solar PV and batteries contribute value and services alongside traditional grid assets.

Solar PV and batteries play an important role in the future electricity grid, but decisions made today will encourage vastly different outcomes.

PATH 2 GRID DEFECTION

Another path favors non-exporting solar PV, behind-the-meter solar-plus-battery systems, and ultimately, actual grid defection resulting in an overbuilt system with excess sunk capital and stranded assets on both sides of the meter.

THREE CATEGORIES OF ACTION

The electricity industry needs to act 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:
    - *Locational*, allowing some form of congestion pricing or incentives, as is done in some city centers and elsewhere
    - *Temporal*, allowing for continued evolution of time-of-use pricing and real-time pricing
    - *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 acknowledged and shared from 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.

BUSINESS MODELS FOR THE SOLAR-PLUS-BATTERY FUTURE

Grid-connected, net-metered solar dominates current DER business models. The customer makes decisions on placement, size, and use, a third-party provide performs installation (and frequently maintenance) and provides financing, and the host utility performs interconnection and provides export compensation. As DER technologies improve, costs decline, and customers increasingly seek distributed energy resources to meet their local energy needs, current business models will need to evolve. The pace and direction of that evolution will depend on changes in pricing mechanisms and regulatory constructs. Several business models we believe are valuable today or will be valuable in the future include:

Grid-Optimized Smart Solar
(e.g., smart inverter-enabled, islandable solar)

The majority of distributed solar PV installed today utilizes older, less-sophisticated inverters giving the system owners “dumb” solar, and at points, creating distribution system performance challenges for grid operators. Project developers can, and should, more readily offer customers grid-optimized smart solar that includes smart inverters with the capability for islanding, improved voltage ride through, and power quality management (e.g., reactive power support, etc.). Grid operators and utilities who stand to benefit from these more sophisticated systems through improved distribution system operability could help project developers accommodate the premium of the controls components with reduced and expedited interconnection fees and processes. Similarly, grid operators and utilities can send new price signals and more transparently share data with customers and third-party providers, such as to encourage solar PV panel orientation that more fully takes into account not only an individual customer’s load profile but also distribution circuit/feeder and macrogrid peaks both by timing and locational congestion.

Total Energy Service (a.k.a. Behind-the-Meter Optimization)*

As the portfolio of distributed energy resources available to customers grows in number, volume, diversity, and sophistication—including everything from on-site generation, to storage, to smarter appliances—customers will increasingly value service providers who can offer total energy solutions. A total energy service package, at its fullest, would include energy assessments, efficiency improvements, actual DERs (e.g., solar PV, smart appliances, batteries, controls, etc.), financing, monitoring, and management of the same. The integrated combination of these assets would allow customers new capabilities, such as responding dynamically to changes in pricing, adjusting consumption of on-site generation to maximize or minimize export, participation in demand-response markets, and other opportunities.

Utility-Coordinated, Customer-Sited Systems

At the intersection of new rate structures and new business models lies the opportunity for utilities to play an expanded control and coordination role for customers with solar-plus-battery systems. Different from battery-ready solar, in this model, utilities will more directly control the inverters, charge controllers, and other components in a customer-sited system. Further, iterations of this model exist where the utility could actually own and rate base the battery and/or the controls components in the customer-sited system as well.

Utilities as Finance Providers

Where utilities and grid operators are ready to manage and leverage higher penetrations of solar-plus-battery systems on their distribution systems, these actors can stimulate their broader adoption by acting as DER financiers. In this model, utilities leverage their comparatively larger balance sheets, lower costs of capital, ability to purchase and negotiate at scale, and established relationship with end-use customers to connect customers with financing solutions and system installers. This would most likely manifest itself in on-bill financing options for customers to install solar-plus-battery systems, and a matchmaking service with pre-qualified local installers. This model presents opportunities especially for customers who are not able to secure affordable financing through the private sector.

Distributed Systems Coordinator
(e.g., Aggregators or Virtual Utilities)*

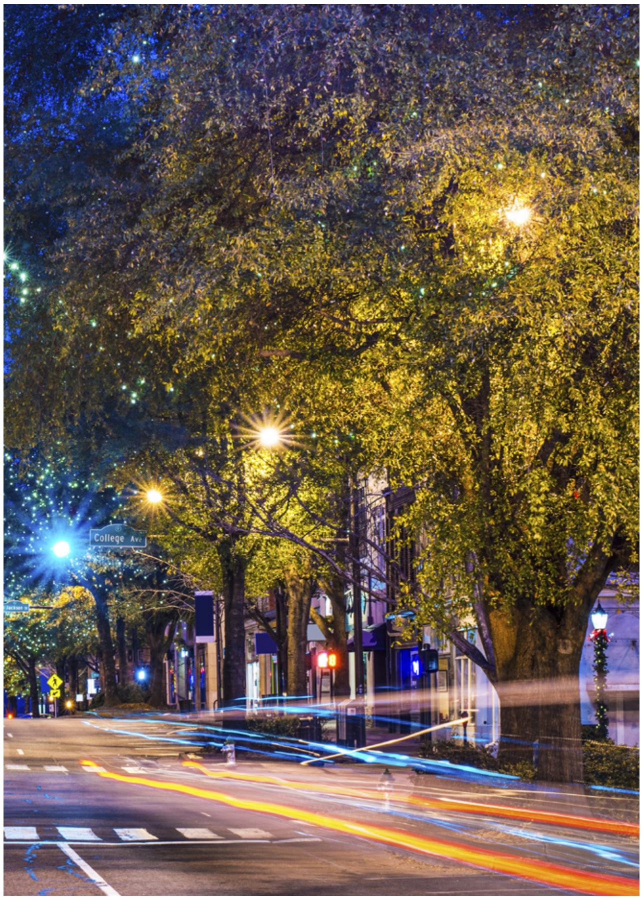
Where total energy services offer to coordinate many different distributed energy resources at one location for a single customer, a distributed system coordinator (DSC) would offer to coordinate similar systems (e.g., smart solar, distributed batteries, or electric vehicles) across many customers. As coordinator, the DSC could leverage the larger capacity and functionality of many systems to aggregate them, and bid them into local markets to earn revenue from sales of energy, capacity, or other ancillary services. DSCs could incent customer participation in their aggregated system through discounts or coupons for initial investments, monthly participation dividends, or in-kind system warranties. This business model can be especially supportive of regulatory models like distribution system operator (DSO),[48] distributed system platform (DSP),[49] and transactive grid approaches.[50]

** = Model where utilities or third parties could act as the lead solution provider depending on the regulatory environment.*

MARKET PHASES OF OPPORTUNITY

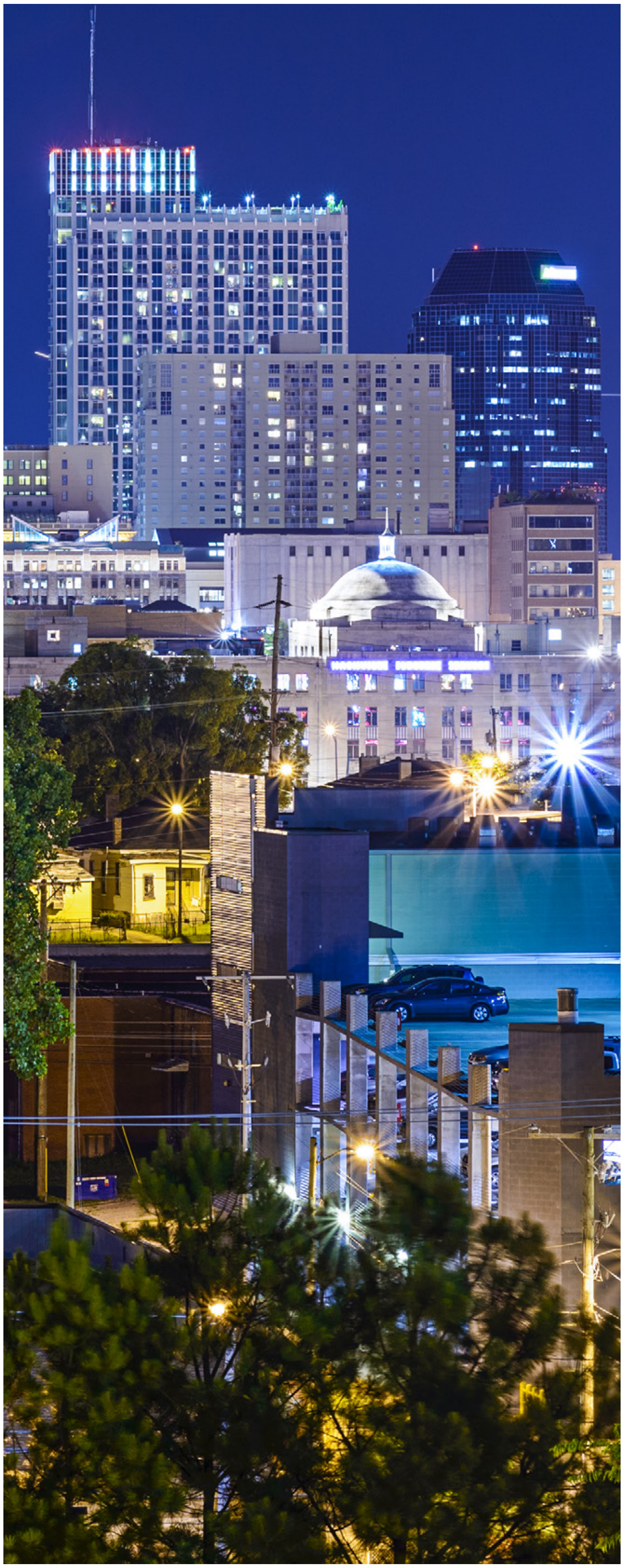
The time frame for making such decisions with long-lasting implications for the future grid is relatively short, and is shorter and more urgent for some geographies than others. Three distinct market phases define the window's time frame:

- *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/backup power and environmental benefits that are not readily available from traditional retail service. 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. As grid-connected solar-plus-battery systems begin to offer economic savings compared to traditional retail electric service alone, it is in this place, at this time, that rate structures and business models can most dramatically affect the configuration of a customer's system to the sole benefit of the customer or the shared benefit of 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. In this phase, if utilities can identify where and how grid-connected solar-plus-battery systems are of the most value to the distribution and macrogrid systems, there is an opportunity to streamline and efficiently manage the growing number of interconnections. However, there is a risk that if utilities make interconnection and transaction with the grid too onerous, customers will pursue complete grid defection.



CONCLUSION

Regardless of how they are implemented, solar-plus-battery systems will play an important role in the electricity system of the future. For customers, they promise lower and more stable pricing; secondary values such as reliability; and a low-carbon alternative to fossil-fueled power plants. However, without a dramatic evolution of our electricity system to accommodate them, they will play the role of disruptor, with ever-increasing levels of load defection and some portion of actual grid defection straining incumbent electricity system generators and the customers who depend solely on the grid for their electric service. If, on the other hand, incumbent electricity system players are able to quickly recognize, and price, the values that solar-plus-battery systems provide, then these systems can play a very different role, by lowering costs for distribution grid operators, providing values laterally to other customers on the distribution grid, and reducing high costs associated with peak load. But to make this latter path a reality we will need pricing, business model, and regulatory changes, all designed with the goal of giving distributed solar-plus-storage systems a chance to compete on a level playing field with other resources on the grid. Given the fast-approaching and rapidly improving economics of these technologies, it is critical that these reforms happen quickly, prior to investments or investment pressure for systems that are designed primarily for load defection alone.



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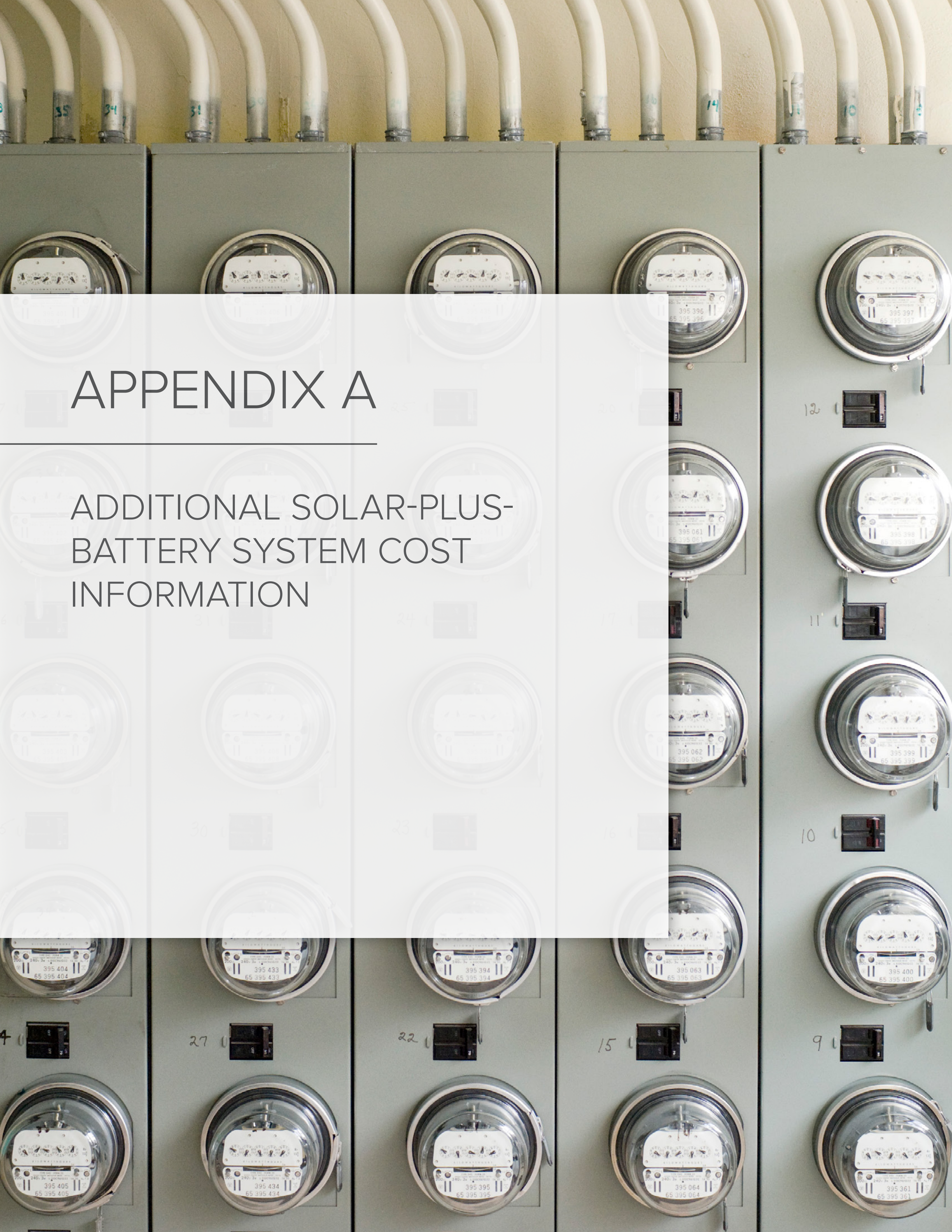
APPENDIX A

ADDITIONAL SOLAR-PLUS-BATTERY SYSTEM COST INFORMATION



APPENDIX A

ADDITIONAL SOLAR-PLUS-BATTERY SYSTEM COST INFORMATION

SOLAR PV

All solar PV costs were normalized to 2012 U.S. dollars using the Bureau of Labor Statistics Consumer Price Index Inflation Calculator. Some data sources had merged PV cost curves, combining residential and commercial systems for average market costs. In these combined market data cases, we utilized market cost deltas from other references to create data resolution for residential and commercial costs.

The PV costs use total installed costs, and therefore include a grid-tied inverter. To separate PV costs from the inverter, we used the BNEF *PV Market Outlook* report as a reference because it included disaggregated PV, including separate values for the PV module, inverter, and balance of systems.

With this data, we calculated the proportion of total installed PV costs that came from the inverter alone. The average, 8%, was used to separate the installed curve into separate “PV without inverter” and “inverter” values.

The inverter included in grid-connected PV systems is a grid-tied inverter. A grid-tied inverter is not capable of islanding or providing other off-grid capabilities. In contrast, an off-grid inverter can operate without a grid connection and includes a battery charging system, additional control capabilities, and additional hardwire and wiring (but not batteries). An off-grid inverter is 25–30% more expensive than a grid-tied inverter.[h] Using this as our basis, we applied a 25% increase to the commercial inverter cost curve and a 30% increase to the residential inverter cost.

BATTERIES

BNEF’s battery projections covered the period 2012–2030. In order to perform our modeling through 2050, we conservatively held the battery price reduction percentage constant year-over-year through 2050. Our final projection applied a 1.9% reduction to each year’s price, resulting in $99/kWh by 2050. To arrive at 1.9%, we considered multiple best-fit curves, and selected a power-fit trend line as the most conservative and realistic forward projection of battery costs. We chose to use only the 2021–2030 data for our 1.9% annual price reduction since this range presented a steady and much more conservative outlook, compared to 2012–2020, which varied by 4–15% each year.

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[h] The 25–30% cost premium is based on confidential interviews with major inverter suppliers.

APPENDIX B

ADDITIONAL TECHNICAL PERFORMANCE ASSUMPTIONS

APPENDIX B

ADDITIONAL TECHNICAL PERFORMANCE ASSUMPTIONS

This appendix includes a description of a number of the detailed technical performance assumptions used in the modeling.

PARAMETER	VALUE	DESCRIPTION	SOURCE
Solar panel lifetime	25 years	The expected lifetime of the solar PV modules.	This is typical of the lifetime warranty that solar panel manufacturers offer
Performance de-rate	78%	Actual installed performance as compared to laboratory performance. 100% would match laboratory performance.	Professional experience
Net installed capacity limit (residential)	20 kW_p	Represents a rough limit due to available PV array installation area. Actual limit will vary based on roof orientation/tilt, area, and PV array efficiency.	Assumed based on an available roof area of a typical home.
Net installed capacity limit (commercial)	None	Commercial space limits will vary substantially by business type and location, so were not included.	Assumed
Installed cost	Varies by year	See Appendix E: Financial Assumptions	
PV slope	Matched to latitude	The angle at which the PV panels are mounted relative to horizontal	Standard industry practice is to set the slope equal to latitude.

Table A1 – PV array technical assumptions

Battery technical assumptions

A battery enables an off-grid system to store energy and moderate power flows to maximize the operational efficiency of the system. A battery is a critical component of most hybrid power systems.

The battery used in the model is intended to represent a generic battery with 1 kWh of capacity. However, due to its current promise as an efficient, durable, shelf-stable battery with excellent power characteristics, lithium-ion (in particular $LiFePO_4$) was used as a basis for specification development. There are many promising technologies that may exceed both the technical and economic performance of these batteries, including advanced lead acid, other novel chemistries, or flow batteries. The authors do not take a position on which chemistry is superior, but have consolidated professional experience with subject matter expert (SME) interviews and a literature review to develop the battery model used in the analysis. It is clear that the storage technology of the future will be low(er) cost, have high roundtrip storage efficiency, and have strong power performance relative to energy storage capabilities.

PARAMETER	VALUE	DESCRIPTION	SOURCE
Capacity	1 kWh	The nominal storage capacity of the battery	Author-imposed selection to make analysis generic and transferable
Calendar life (float life)	15 years	The maximum lifetime of the battery, regardless of use	Professional experience validated with anecdotal review of $LiFePO_4$ specification sheets
Lifetime throughput	3,750 cycles at 80% depth of discharge	The total amount of energy that can be cycled through the battery before it needs replacement	Professional experience validated with anecdotal review of $LiFePO_4$ specification sheets
Roundtrip efficiency	90%	The round trip DC-to-storage-to-DC efficiency of the battery bank	Professional experience
Minimum state of charge	20%	The relative state of charge below which the battery bank is never drawn	Professional experience
Maximum charge power	1 kW	The maximum power that can be used to charge each battery	Professional experience validated with anecdotal review of $LiFePO_4$ specification sheets
Maximum discharge power	3 kW	The maximum power that each battery can discharge	Professional experience validated with anecdotal review of $LiFePO_4$ specification sheets
Installed cost	Varies by year	See Appendix E: Financial Assumptions	Review of literature validated with SME interviews (see main report for full source list)

Table A2 – Battery technical assumptions

Converter (inverter/rectifier) technical assumptions

A converter converts electricity from alternating current (AC) to direct current (DC) and vice-versa. A converter is composed of two major components: an inverter that converts AC electricity to DC, and a rectifier (aka charger) that converts DC to AC. Grid-tied inverter costs were derived from the PV costs listed in Appendix TK. We calculated the cost breakdown based on the BNEF PV Market Outlook report. It included disaggregated PV including separate values for the PV module, inverter, and balance of systems. The on-grid inverter costs represented from 7.8% to 9.5%, depending on the year. The average percentage, 8%, was used to derive the inverter costs from the installed PV cost curves.

The inverter installed in typical grid-connected PV systems is a grid-tie (aka grid-following) inverter. A grid-tied inverter is not capable of islanding or providing other off-grid capabilities. In contrast, an off-grid inverter can operate without a grid connection and includes a battery charging system, grid controls, and additional hardwire and wiring (but not batteries). An off-grid inverter is 25-30% more expensive than a grid-tied inverter.[i] Using this as our basis, we applied a 25% increase to the commercial inverter cost curve and a 30% increase to the residential inverter cost.

PARAMETER	VALUE	DESCRIPTION	SOURCE
Inverter type	Grid forming	An off-grid inverter can operate without a grid connection and includes a battery charging system, grid controls, and additional hardwire and wiring (but not batteries)	
Rectifier/charger efficiency (AC to DC)	90%	The efficiency of converting electricity from AC to DC	Professional experience validated with SME interviews
Inverter efficiency (DC to AC)	95%	The efficiency of converting electricity from DC to AC	Professional experience validated with SME interviews
Off-grid inverter cost premium (residential/ commercial)	30% / 25%	An off-grid inverter is more expensive than a grid-tie inverter	Major inverter supplier that asked not to be identified
Installed cost	Varies by year	See Appendix E: Financial Assumptions	Review of literature validated with SME interviews (see main report for full source list)

Table A3 – Inverter technical assumptions

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[i] The 25–30% cost premium is based on interviews with a major inverter supplier that asked not to be identified.

APPENDIX C

GRID SERVICE TECHNICAL ASSUMPTIONS

APPENDIX C

GRID SERVICE TECHNICAL ASSUMPTIONS

Our analysis used several rate variables to model a grid connection. The rate variables allowed us to define the cost structure of buying electricity from the grid and selling it back through net energy metering.

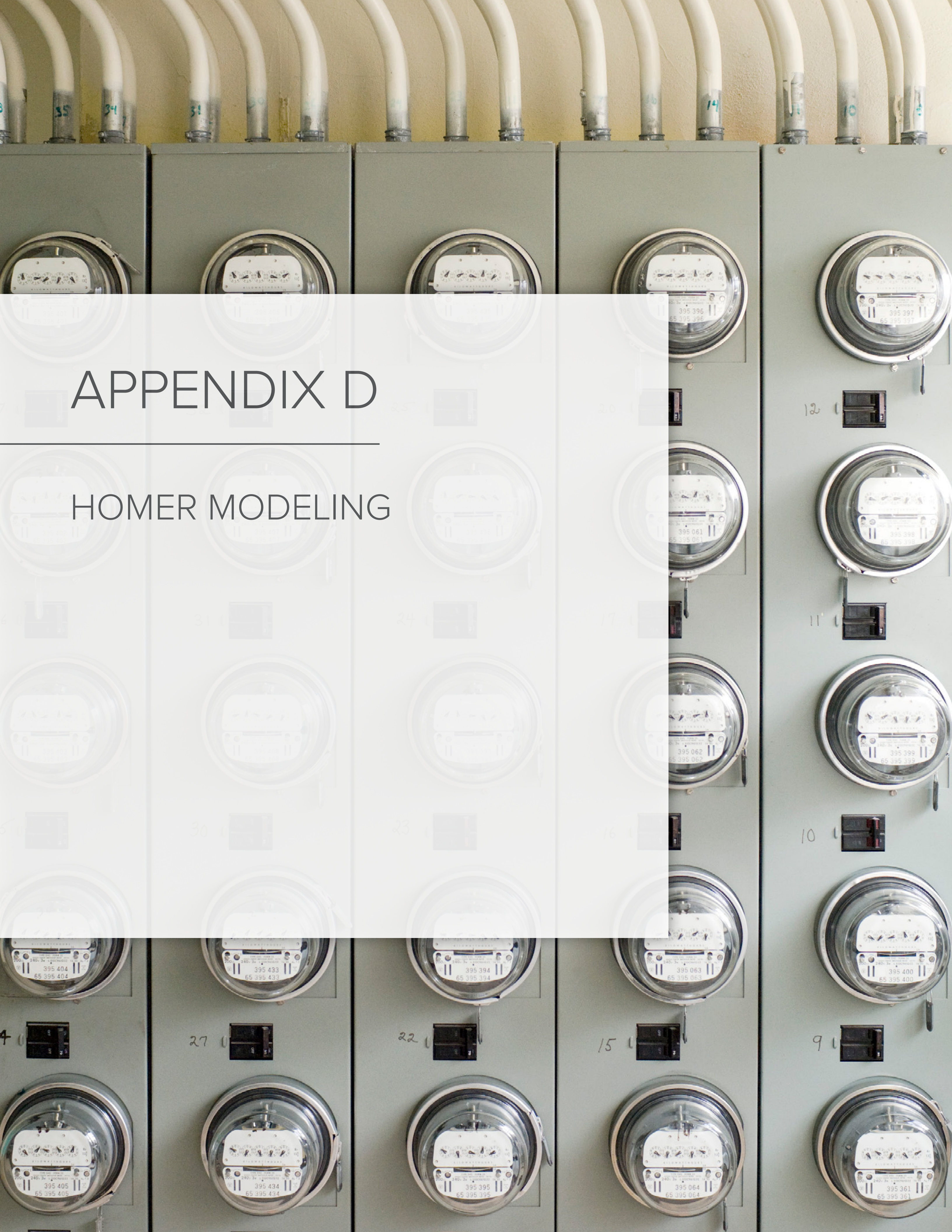
Using scheduled rates we were able to set specific summer and winter schedules to match the rates found in the Genability database. The residential models used a volumetric power price only, which did not change based on time of day or month in the year. Most of the commercial customers had different summer and winter rates, , demand and fixed charges, which are further described in rate Table 2.

PARAMETER	VALUE	DESCRIPTION	SOURCE
Rate type	Scheduled rate	Allows different grid rates to be applied by an hourly and monthly schedule.	Genability
Power price	Varies based on location (see table 2)	The cost of buying power from the grid in $/kWh (i.e., volumetric rate).	Genability (with an annual 3%-real increase)
Demand rate	Varies based on location (see rate table TK) $0.00/kW/mo for all residential models	The monthly fee charged by the utility on the monthly peak demand.	Genability (with an annual 3%-real increase)
System fixed O&M cost (this variable is found in the Economic Inputs section of HOMER)	Varies based on location (see rate table TK) $0.00/year for all residential models	The fixed recurring annual costs that occur regardless of the size or architecture of the system. We used this variable to capture the rate fixed charges since the grid inputs do not have a place to input this cost.	Genability (with an annual 3%-real increase)
Sellback rate	$0.00/kWh	The price that the utility pays for power sold back to the grid. Under net metering, the sellback rate only applies to net excess generation.	Conservatively set to $0.
Time period	All Week	Signifies when the rate schedule applies; other choices are weekdays only or weekends only.	Genability
Net metering	Annual billing period	This setting allows energy to be sold back to the grid at the retail rate. At the end of the billing period (set to annually in our model), charges for the net amount purchased are calculated (purchases minus sales). If the net amount is negative, meaning more is sold that bought over the billing period, the utility pays according to the sellback rate.	
Emissions factors	Carbon dioxide (g/kWh) = 632 Sulfur dioxide (g/kWh) = 2.74 Nitrogen oxides (g/kWh) = 1.34	Emissions factors from grid power of various pollutants. These can be changed to match the generation mix of a particular area.	Default HOMER values were unchanged since this was not a core analysis area of our study.

Table A4 – Grid connection technical assumptions

PARAMETER	VALUE	DESCRIPTION	SOURCE
Interconnection charge	$0	One-time fee charged by the utility for connecting to the grid.	Due to the complexity in interconnection charges from utility to utility, we chose to leave this value unchanged. Adding this charge presents an opportunity for further research to model all applicable charges for a specific utility and customer.
Standby charge	$0.00/year	Annual fee charged by the utility for providing backup grid power.	Due to the complexity in interconnection charges from utility to utility, we chose to leave this value unchanged. Adding this charge presents an opportunity for further research to model all applicable charges for a specific utility and customer.
Maximum grid purchase capacity	Allowed for various levels ranging from 0kW up to but not including the peak demand for each geography. Additionally a value of 1000kW was included to represent an unlimited grid connection. *Net metered models used a value of 1000kW only.	Maximum amount of power that can be drawn from the grid. HOMER finds the optimal value of grid purchase capacity per simulation time step.	Tested a large range of values in the non-net metered models only. *To match current net metering schemes, no limit was set to the grid connection level.

Table A4 – Grid connection technical assumptions (Continued)



APPENDIX D

HOMER MODELING

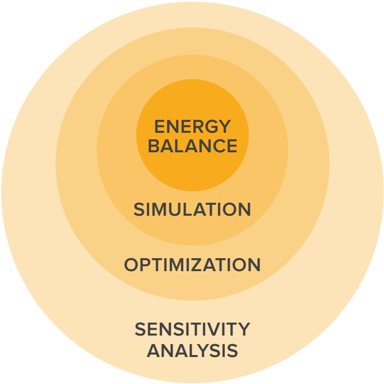
APPENDIX D

HOMER MODELING

The HOMER® software model uses a chronological annual simulation to determine how systems with different sets of equipment can be used meet an electrical load. The annual simulation includes an hour-by-hour energy balance that determines how energy generators and storage are dispatched. This simulation underpins all analyses in HOMER.

The input data for the simulation includes equipment costs, performance data, solar and fuel resource data, efficiency, and equipment sizes. Based on these inputs, HOMER simulates how these different systems will perform. By varying the HOMER capacity of installed equipment within a user-defined search space determines the optimal set of equipment in a location. HOMER's optimization ranks the simulated systems by net present cost (NPC), which accounts for all of the discounted operating costs over the system's lifetime.

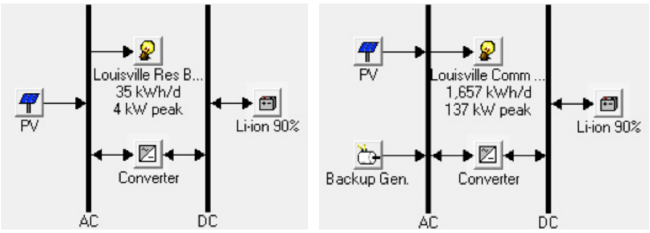
In addition to varying the capacity of the installed equipment, the user may also use HOMER's automated sensitivity analyses by varying the underlying assumptions for a location—for example, the cost of diesel fuel or the installed cost of equipment. Sensitivity analysis is different from optimization because it varies things that a system designer cannot control. This enables the model to make a distinction between things the user can control in the design (e.g., the size of a diesel generator) from those the user can't control (e.g., diesel fuel price). Together, simulation, optimization, and sensitivity analysis form the foundation for HOMER analysis:



An hourly simulation includes 8,760 annual energy balances in a simulation (one for each hour of the year). Optimizations encompass a number of chronological annual simulations, and a sensitivity analysis encompasses a number of optimizations. Together, these can be used to determine what system is optimally suited for a particular location, and how that optimal system might change in the face of data uncertainty or future variation.

Applying the HOMER model to the market

Using the HOMER software, we developed energy models for representative residential and commercial off-grid markets in each geographic region. Model inputs including component costs, electrical load profiles, fuel prices, and geographical location were based on the base case data. All residential sites were powered exclusively by PV and battery storage. Commercial sites were modeled both with and without a standby generator sized to 110% of the system peak load. In all systems, the PV array was modeled to include a dedicated inverter to allow it to connect directly to the AC bus. The battery bank was connected to the system on the DC bus. The converter to transfer electricity from the AC to DC bus was modeled to be a grid-forming inverter with battery charger. Each location had a different load profile, based on NREL OpenEI data. The HOMER model schematic for the Louisville residential and commercial models can be seen below.



APPENDIX E

FINANCIAL ASSUMPTIONS SECTION

APPENDIX E

FINANCIAL ASSUMPTIONS SECTION

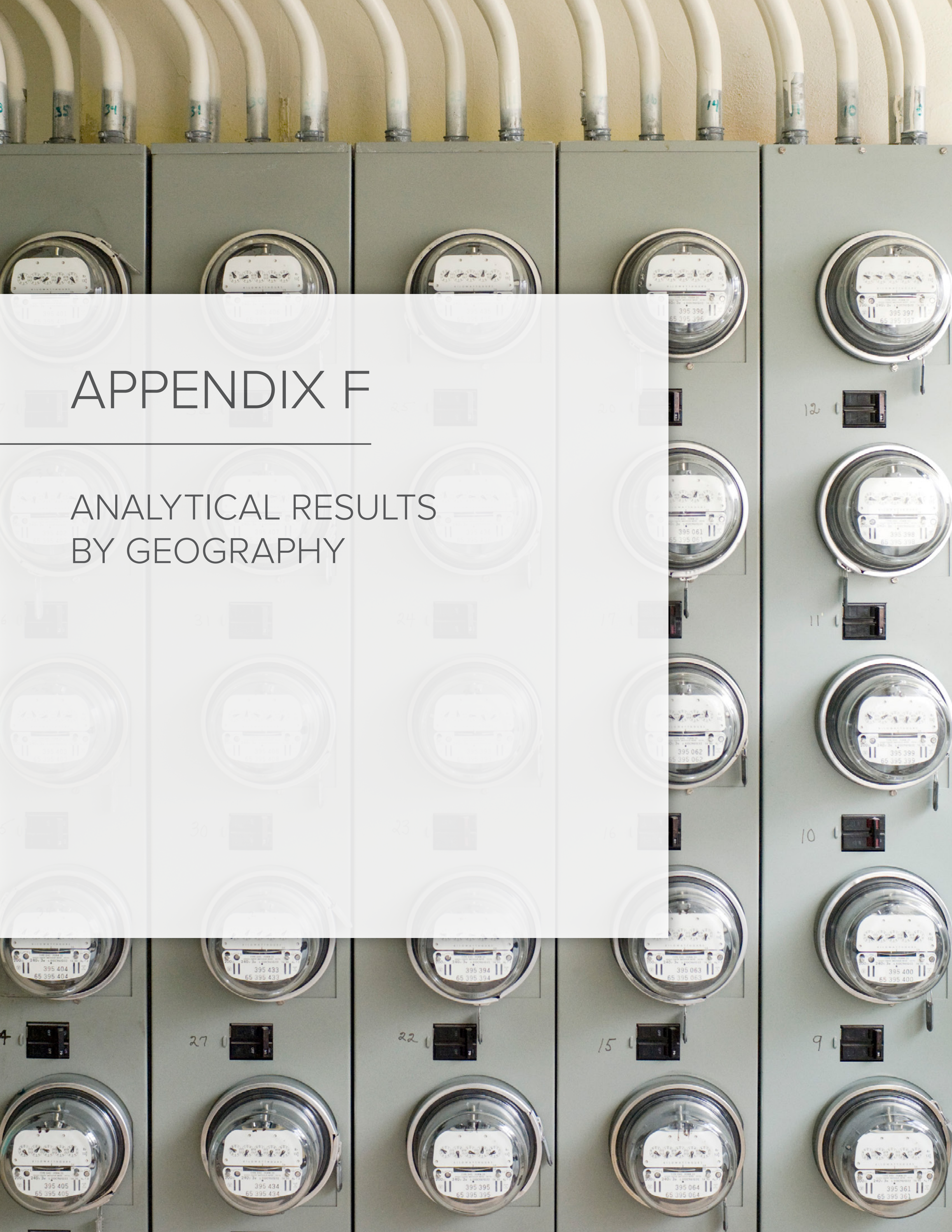
For the purposes of this report, the researchers made several key financial assumptions:

1. ***First-Party (Host-Owned) Ownership of Residential and Commercial Systems***—Many solar PV systems in the U.S. are built using a third-party financing model where the system host pays a per kWh rate to a third-party financier, allowing for system cost recovery over the life of the power purchase agreement. The third-party finance model is largely based upon the fact that third-party finance entities can utilize more tax credits than most property owners. However, since not all of the current tax credits are scheduled to extend far into the future, the researchers chose to model first-party system ownership.
2. ***The Models Only Consider Federal Tax Credits***—To control for potential incentives, only federal tax credits were considered for the models; no local or state tax treatments were applied. No assumptions were made about the renewal of key federal tax credits.
3. ***Assumed Discount Rates***—These rates were used to discount system operation and maintenance costs and forecast soft costs to the projected construction date. This allowed the researchers to determine the net present value of systems built in the future.

Interest Rates (weighted average cost of capital)		
Year	Residential	Commercial
2014	8.8%	9.5%
2015	8.2%	8.7%
2016	7.8%	8.7%
2017	5.1%	5.4%
2018	4.9%	4.9%
2019	4.6%	4.5%
2020	4.6%	4.4%
2021	4.6%	4.4%
2022	4.6%	4.4%
2023	4.6%	4.4%
2024	4.6%	4.4%
2025	4.6%	4.4%
2026	4.6%	4.4%
2027	4.6%	4.4%
2028	4.6%	4.4%
2029	4.6%	4.4%
2030	4.6%	4.4%
2031	4.6%	4.4%
2032	4.6%	4.4%
2033	4.6%	4.4%
2034	4.6%	4.4%
2035	4.6%	4.4%
2036	4.6%	4.4%
2037	4.6%	4.4%
2038	4.6%	4.4%
2039	4.6%	4.4%
2040	4.6%	4.4%
2041	4.6%	4.4%
2042	4.6%	4.4%
2043	4.6%	4.4%
2044	4.6%	4.4%
2045	4.6%	4.4%
2046	4.6%	4.4%
2047	4.6%	4.4%
2048	4.6%	4.4%
2049	4.6%	4.4%
2050	4.6%	4.4%

APPENDIX F

ANALYTICAL RESULTS BY GEOGRAPHY



APPENDIX F

ANALYTICAL RESULTS BY GEOGRAPHY

COMMERCIAL TABLES - WESTCHESTER, NY

Westchester, NY - Commercial - Non-Grid Exporting System

Year	Winter Power Price	Winter Demand Rate	Summer Power Price	Summer Demand Rate	Fixed Charges	Grid	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Capital Cost	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Ann. Cost	Operating Cost	COE	PV Production	Grid Purchases	Grid Sales	Grid Net Purchases	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Excess Electricity	Battery Autonomy	Battery Throughput
	$/kWh	$/kW/mo.	$/kWh	$/kW/mo.	$/yr	kW	kW	kWh	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	%	kWh/yr	hr	kWh/yr
2014	0.114	20.267	0.114	25.614	1530	125	0	0	0	0	915,707	0	0	97,028	0	97,028	97,028	0.168	0	577,407	0	577,407	577,407	577,408	0	0	0	0
2016	0.121	21.501	0.121	27.174	1623	123	75	0	0	99,000	1,013,521	9,835	0	90,851	0	100,686	90,851	0.174	97,347	481,044	0	481,044	578,391	577,396	0.17	996	0	0
2018	0.128	22.81	0.128	28.829	1722	123	100	0	0	158,000	1,483,326	11,098	0	93,095	0	104,193	93,095	0.18	129,796	455,783	0	455,783	585,579	577,396	0.21	8,184	0	0
2020	0.136	24.199	0.136	30.584	1827	123	125	0	0	178,750	1,619,523	11,931	0	96,167	0	108,098	96,167	0.187	162,245	436,935	0	436,935	599,180	577,396	0.24	21,785	0	0
2022	0.144	25.673	0.144	32.447	1938	123	125	0	0	165,000	1,693,515	11,013	0	102,023	0	113,036	102,023	0.196	162,245	436,935	0	436,935	599,180	577,396	0.24	21,785	0	0
2024	0.153	27.237	0.153	34.423	2056	123	150	0	0	184,500	1,772,147	12,315	0	105,970	0	118,285	105,970	0.205	194,694	422,326	0	422,326	617,020	577,396	0.27	39,625	0	0
2026	0.162	28.895	0.162	36.519	2181	123	225	250	50	313,593	1,855,640	20,931	2,173	100,754	0	123,858	102,926	0.215	292,041	349,081	0	349,081	641,122	577,404	0.4	51,089	3.03	47,652
2028	0.172	30.655	0.172	38.743	2314	117	325	700	125	498,222	1,917,764	33,255	5,477	89,273	0	128,004	94,750	0.222	421,837	247,333	0	247,333	669,170	577,318	0.57	56,699	8.5	132,646
2030	0.183	32.522	0.183	41.103	2455	115	425	1,075	175	649,256	1,954,700	43,336	7,667	79,467	0	130,470	87,134	0.226	551,633	161,956	0	161,956	713,589	577,308	0.72	80,836	13.05	209,116
2032	0.194	34.503	0.194	43.606	2605	112	475	1,200	200	720,890	2,013,231	48,117	8,354	77,905	0	134,376	86,259	0.233	616,532	131,215	0	131,215	747,747	577,283	0.77	107,829	14.57	236,178
2034	0.206	36.604	0.206	46.262	2763	112	475	1,225	200	715,728	2,071,185	47,772	8,336	82,136	0	138,245	90,472	0.239	616,532	129,190	0	129,190	745,722	577,283	0.78	105,221	14.87	238,424
2036	0.218	38.833	0.218	49.079	2932	111	500	1,225	200	735,714	2,134,085	49,106	8,199	85,137	0	142,443	93,337	0.247	648,980	121,785	0	121,785	770,765	577,283	0.79	128,896	14.87	243,499
2038	0.232	41.198	0.232	52.068	3110	111	500	1,250	200	736,225	2,205,054	49,141	8,222	89,817	0	147,180	98,039	0.255	648,980	120,035	0	120,035	769,015	577,283	0.79	126,645	15.17	245,441
2040	0.246	43.707	0.246	55.239	3300	89	750	4,000	325	1,359,040	2,260,142	90,711	24,219	35,926	0	150,857	60,146	0.261	973,471	19,615	0	19,615	993,087	577,296	0.97	329,115	48.56	333,430
2042	0.261	46.369	0.261	58.603	3501	89	750	4,000	325	1,350,400	2,271,103	90,135	23,827	37,627	0	151,588	61,454	0.263	973,471	19,615	0	19,615	993,087	577,296	0.97	329,115	48.56	333,430
2044	0.277	49.192	0.277	62.172	3714	89	750	4,000	325	1,334,500	2,276,552	89,073	23,447	39,431	0	151,952	62,879	0.263	973,471	19,615	0	19,615	993,087	577,296	0.97	329,115	48.56	333,430
2046	0.293	52.188	0.293	65.958	3940	89	750	4,000	325	1,326,420	2,291,632	88,534	23,079	41,345	0	152,959	64,425	0.265	973,471	19,615	0	19,615	993,087	577,296	0.97	329,115	48.56	333,430
2048	0.311	55.367	0.311	69.975	4180	89	750	4,000	325	1,311,040	2,300,021	87,507	22,635	43,376	0	153,519	66,011	0.266	973,471	19,615	0	19,615	993,087	577,296	0.97	329,115	48.56	333,430
2050	0.33	58.738	0.33	74.236	4434	89	750	4,000	325	1,303,440	2,319,524	87,000	22,290	45,531	0	154,820	67,820	0.268	973,471	19,615	0	19,615	993,087	577,296	0.97	329,115	48.56	333,430

Westchester, NY - Commercial - With Exports to Grid (Net Energy Metering)

Year	Winter Power Price	Winter Demand Rate	Summer Power Price	Summer Demand Rate	Fixed Charges	Grid	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Capital Cost	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Ann. Cost	Operating Cost	COE	PV Production	Grid Purchases	Grid Sales	Grid Net Purchases	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Excess Electricity	Battery Autonomy	Battery Throughput
	$/kWh	$/kW/mo.	$/kWh	$/kW/mo.	$/yr	kW	kW	kWh	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	%	kWh/yr	hr	kWh/yr
2014	0.114	20.267	0.114	25.614	1530	1,000	0	0	0	0	918,397	0	0	97,313	0	97,313	97,313	0.169	0	577,430	0	577,430	577,430	577,431	0	0	0	0
2016	0.121	21.501	0.121	27.174	1623	1,000	425	0	0	561,000	925,003	55,731	0	36,161	0	91,892	36,161	0.102	551,633	350,545	324,748	25,797	902,178	577,431	0.61	0	0	0
2018	0.128	22.81	0.128	28.829	1722	1,000	450	0	0	711,000	1,215,777	49,943	0	35,457	0	85,400	35,457	0.092	584,083	347,257	353,910	-6,652	931,340	577,431	0.63	0	0	0
2020	0.136	24.199	0.136	30.584	1827	1,000	450	0	0	643,500	1,207,070	42,951	0	37,616	0	80,568	37,616	0.087	584,083	347,257	353,910	-6,652	931,340	577,431	0.63	0	0	0
2022	0.144	25.673	0.144	32.447	1938	1,000	450	0	0	594,000	1,191,891	39,647	0	39,907	0	79,555	39,907	0.085	584,083	347,257	353,910	-6,652	931,340	577,431	0.63	0	0	0
2024	0.153	27.237	0.153	34.423	2056	1,000	450	0	0	553,500	1,187,803	36,944	0	42,338	0	79,282	42,338	0.085	584,083	347,257	353,910	-6,652	931,340	577,431	0.63	0	0	0
2026	0.162	28.895	0.162	36.519	2181	1,000	450	0	0	531,000	1,203,932	35,442	0	44,916	0	80,358	44,916	0.086	584,083	347,257	353,910	-6,652	931,340	577,431	0.63	0	0	0
2028	0.172	30.655	0.172	38.743	2314	1,000	450	0	0	522,000	1,235,914	34,842	0	47,651	0	82,493	47,651	0.089	584,083	347,257	353,910	-6,652	931,340	577,431	0.63	0	0	0
2030	0.183	32.522	0.183	41.103	2455	1,000	450	0	0	508,500	1,265,891	33,941	0	50,553	0	84,494	50,553	0.091	584,083	347,257	353,910	-6,652	931,340	577,431	0.63	0	0	0
2032	0.194	34.503	0.194	43.606	2605	1,000	450	0	0	508,500	1,312,016	33,941	0	53,632	0	87,573	53,632	0.094	584,083	347,257	353,910	-6,652	931,340	577,431	0.63	0	0	0
2034	0.206	36.604	0.206	46.262	2763	1,000	450	0	0	504,000	1,356,450	33,640	0	56,898	0	90,538	56,898	0.097	584,083	347,257	353,910	-6,652	931,340	577,431	0.63	0	0	0
2036	0.218	38.833	0.218	49.079	2932	1,000	450	0	0	499,500	1,403,864	33,340	0	60,363	0	93,703	60,363	0.101	584,083	347,257	353,910	-6,652	931,340	577,431	0.63	0	0	0
2038	0.232	41.198	0.232	52.068	3110	1,000	450	0	0	499,500	1,458,940	33,340	0	64,039	0	97,379	64,039	0.105	584,083	347,257	353,910	-6,652	931,340	577,431	0.63	0	0	0
2040	0.246	43.707	0.246	55.239	3300	1,000	450	0	0	495,000	1,512,870	33,040	0	67,939	0	100,979	67,939	0.108	584,083	347,257	353,910	-6,652	931,340	577,431	0.63	0	0	0
2042	0.261	46.369	0.261	58.603	3501	1,000	450	0	0	495,000	1,574,858	33,040	0	72,077	0	105,116	72,077	0.113	584,083	347,257	353,910	-6,652	931,340	577,431	0.63	0	0	0
2044	0.277	49.192	0.277	62.172	3714	1,000	450	0	0	490,500	1,636,122	32,739	0	76,466	0	109,206	76,466	0.117	584,083	347,257	353,910	-6,652	931,340	577,431	0.63	0	0	0
2046	0.293	52.188	0.293	65.958	3940	1,000	450	0	0	490,500	1,705,890	32,739	0	81,123	0	113,862	81,123	0.122	584,083	347,257	353,910	-6,652	931,340	577,431	0.63	0	0	0
2048	0.311	55.367	0.311	69.975	4180	1,000	450	0	0	486,000	1,775,408	32,439	0	86,064	0	118,502	86,064	0.127	584,083	347,257	353,910	-6,652	931,340	577,431	0.63	0	0	0
2050	0.33	58.738	0.33	74.236	4434	1,000	450	0	0	486,000	1,853,932	32,439	0	91,305	0	123,744	91,305	0.133	584,083	347,257	353,910	-6,652	931,340	577,431	0.63	0	0	0

COMMERCIAL TABLES - LOUISVILLE, KY

Louisville, KY - Commercial - Non-Grid Exporting System

Year	Winter Power Price	Winter Demand Rate	Summer Power Price	Summer Demand Rate	Fixed Charges	Grid	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Capital Cost	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Ann. Cost	Operating Cost	COE	PV Production	Grid Purchases	Grid Sales	Grid Net Purchases	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Excess Electricity	Battery Autonomy	Battery Throughput
	$/kWh	$/kW/mo.	$/kWh	$/kW/mo.	$/yr	kW	kW	kWh	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	%	kWh/yr	hr	kWh/yr
2014	0.045	13.249	0.045	13.265	2570	133	0	0	0	0	457,876	0	0	48,516	0	48,516	48,516	0.08	0	604,796	0	604,796	604,796	604,797	0	0	0	0
2016	0.048	14.056	0.048	14.073	2726	133	0	0	0	0	520,226	0	0	51,680	0	51,680	51,680	0.085	0	604,796	0	604,796	604,796	604,797	0	0	0	0
2018	0.051	14.912	0.051	14.93	2892	133	0	0	0	0	780,892	0	0	54,852	0	54,852	54,852	0.091	0	604,796	0	604,796	604,796	604,797	0	0	0	0
2020	0.054	15.82	0.054	15.839	3068	133	0	0	0	0	871,340	0	0	58,159	0	58,159	58,159	0.096	0	604,796	0	604,796	604,796	604,797	0	0	0	0
2022	0.058	16.784	0.058	16.804	3255	133	0	0	0	0	927,797	0	0	61,927	0	61,927	61,927	0.102	0	604,796	0	604,796	604,796	604,797	0	0	0	0
2024	0.061	17.806	0.061	17.827	3453	133	50	0	0	61,500	980,704	4,105	0	61,354	0	65,459	61,354	0.108	67,949	536,850	0	536,850	604,799	604,800	0.11	0	0	0
2026	0.065	18.89	0.065	18.913	3664	132	75	0	0	88,500	1,032,270	5,907	0	62,993	0	68,901	62,993	0.114	101,923	503,874	0	503,874	605,798	604,797	0.17	1,002	0	0
2028	0.069	20.04	0.069	20.065	3887	132	100	0	0	116,000	1,088,309	7,743	0	64,898	0	72,641	64,898	0.12	135,898	475,951	0	475,951	611,849	604,798	0.21	7,052	0	0
2030	0.073	21.261	0.073	21.287	4123	132	100	0	0	113,000	1,143,750	7,542	0	68,799	0	76,341	68,799	0.126	135,898	475,951	0	475,951	611,849	604,798	0.21	7,052	0	0
2032	0.077	22.556	0.077	22.583	4374	132	100	0	0	113,000	1,204,819	7,542	0	72,875	0	80,418	72,875	0.133	135,898	475,951	0	475,951	611,849	604,798	0.21	7,052	0	0
2034	0.082	23.929	0.082	23.958	4641	132	100	0	0	112,000	1,271,498	7,476	0	77,393	0	84,868	77,393	0.14	135,898	475,951	0	475,951	611,849	604,798	0.21	7,052	0	0
2036	0.087	25.387	0.087	25.417	4923	132	125	0	0	138,750	1,340,982	9,261	0	80,245	0	89,506	80,245	0.148	169,872	454,847	0	454,847	624,719	604,799	0.25	19,921	0	0
2038	0.092	26.933	0.092	26.965	5223	132	125	0	0	138,750	1,413,097	9,261	0	85,058	0	94,319	85,058	0.156	169,872	454,847	0	454,847	624,719	604,799	0.25	19,921	0	0
2040	0.098	28.573	0.098	28.607	5541	132	125	0	0	137,500	1,490,921	9,178	0	90,336	0	99,514	90,336	0.165	169,872	454,847	0	454,847	624,719	604,799	0.25	19,921	0	0
2042	0.104	30.313	0.104	30.35	5879	132	125	0	0	137,500	1,573,462	9,178	0	95,846	0	105,023	95,846	0.174	169,872	454,847	0	454,847	624,719	604,799	0.25	19,921	0	0
2044	0.11	32.159	0.11	32.198	6237	132	125	0	0	136,250	1,658,430	9,094	0	101,600	0	110,695	101,600	0.183	169,872	454,847	0	454,847	624,719	604,799	0.25	19,921	0	0
2046	0.117	34.117	0.117	34.159	6617	132	175	125	25	208,435	1,751,076	13,912	803	102,163	0	116,878	102,966	0.193	237,821	405,959	0	405,959	643,780	604,801	0.33	33,032	1.45	22,472
2048	0.124	36.195	0.124	36.239	7020	132	175	125	25	206,439	1,841,379	13,779	785	108,342	0	122,906	109,127	0.203	237,821	405,959	0	405,959	643,780	604,801	0.33	33,032	1.45	22,472
2050	0.132	38.4	0.132	38.446	7447	123	325	725	125	448,367	1,924,894	29,927	4,384	94,169	0	128,480	98,553	0.212	441,668	254,095	0	254,095	695,763	604,742	0.58	53,721	8.4	140,684

Louisville, KY - Commercial - With Exports to Grid (Net Energy Metering)

Year	Winter Power Price	Winter Demand Rate	Summer Power Price	Summer Demand Rate	Fixed Charges	Grid	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Capital Cost	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Ann. Cost	Operating Cost	COE	PV Production	Grid Purchases	Grid Sales	Grid Net Purchases	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Excess Electricity	Battery Autonomy	Battery Throughput
	$/kWh	$/kW/mo.	$/kWh	$/kW/mo.	$/yr	kW	kW	kWh	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	%	kWh/yr	hr	kWh/yr
2014	0.045	13.249	0.045	13.265	2570	1,000	0	0	0	0	458,463	0	0	48,578	0	48,578	48,578	0.08	0	604,807	0	604,807	604,807	604,809	0	0	0	0
2016	0.048	14.056	0.048	14.073	2726	1,000	0	0	0	0	520,890	0	0	51,746	0	51,746	51,746	0.086	0	604,807	0	604,807	604,807	604,809	0	0	0	0
2018	0.051	14.912	0.051	14.93	2892	1,000	0	0	0	0	781,888	0	0	54,922	0	54,922	54,922	0.091	0	604,807	0	604,807	604,807	604,809	0	0	0	0
2020	0.054	15.82	0.054	15.839	3068	1,000	0	0	0	0	872,452	0	0	58,233	0	58,233	58,233	0.096	0	604,807	0	604,807	604,807	604,809	0	0	0	0
2022	0.058	16.784	0.058	16.804	3255	1,000	0	0	0	0	928,977	0	0	62,006	0	62,006	62,006	0.103	0	604,807	0	604,807	604,807	604,809	0	0	0	0
2024	0.061	17.806	0.061	17.827	3453	1,000	425	0	0	522,750	976,314	34,892	0	30,274	0	65,166	30,274	0.069	577,565	364,015	336,773	27,242	941,580	604,809	0.61	0	0	0
2026	0.065	18.89	0.065	18.913	3664	1,000	425	0	0	501,500	982,788	33,473	0	32,124	0	65,598	32,124	0.07	577,565	364,015	336,773	27,242	941,580	604,809	0.61	0	0	0
2028	0.069	20.04	0.069	20.065	3887	1,000	425	0	0	493,000	1,003,613	32,906	0	34,082	0	66,988	34,082	0.071	577,565	364,015	336,773	27,242	941,580	604,809	0.61	0	0	0
2030	0.073	21.261	0.073	21.287	4123	1,000	425	0	0	480,250	1,021,887	32,055	0	36,152	0	68,208	36,152	0.072	577,565	364,015	336,773	27,242	941,580	604,809	0.61	0	0	0
2032	0.077	22.556	0.077	22.583	4374	1,000	425	0	0	480,250	1,054,714	32,055	0	38,344	0	70,399	38,344	0.075	577,565	364,015	336,773	27,242	941,580	604,809	0.61	0	0	0
2034	0.082	23.929	0.082	23.958	4641	1,000	425	0	0	476,000	1,085,560	31,771	0	40,686	0	72,457	40,686	0.077	577,565	364,015	336,773	27,242	941,580	604,809	0.61	0	0	0
2036	0.087	25.387	0.087	25.417	4923	1,000	425	0	0	471,750	1,118,434	31,488	0	43,164	0	74,652	43,164	0.079	577,565	364,015	336,773	27,242	941,580	604,809	0.61	0	0	0
2038	0.092	26.933	0.092	26.965	5223	1,000	450	0	0	499,500	1,156,847	33,340	0	43,876	0	77,216	43,876	0.079	611,540	360,487	367,220	-6,732	972,027	604,809	0.63	0	0	0
2040	0.098	28.573	0.098	28.607	5541	1,000	450	0	0	495,000	1,192,418	33,040	0	46,550	0	79,590	46,550	0.082	611,540	360,487	367,220	-6,732	972,027	604,809	0.63	0	0	0
2042	0.104	30.313	0.104	30.35	5879	1,000	450	0	0	495,000	1,234,893	33,040	0	49,385	0	82,425	49,385	0.085	611,540	360,487	367,220	-6,732	972,027	604,809	0.63	0	0	0
2044	0.11	32.159	0.11	32.198	6237	1,000	450	0	0	490,500	1,275,420	32,739	0	52,391	0	85,130	52,391	0.088	611,540	360,487	367,220	-6,732	972,027	604,809	0.63	0	0	0
2046	0.117	34.117	0.117	34.159	6617	1,000	450	0	0	490,500	1,323,252	32,739	0	55,583	0	88,323	55,583	0.091	611,540	360,487	367,220	-6,732	972,027	604,809	0.63	0	0	0
2048	0.124	36.195	0.124	36.239	7020	1,000	450	0	0	486,000	1,369,454	32,439	0	58,968	0	91,406	58,968	0.094	611,540	360,487	367,220	-6,732	972,027	604,809	0.63	0	0	0
2050	0.132	38.4	0.132	38.446	7447	1,000	450	0	0	486,000	1,423,300	32,439	0	62,562	0	95,000	62,562	0.098	611,540	360,487	367,220	-6,732	972,027	604,809	0.63	0	0	0

COMMERCIAL TABLES - SAN ANTONIO, TX

San Antonio, TX - Commercial - Non-Grid Exporting System

Year	Winter Power Price	Summer Power Price	Fixed Charges	Grid	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Capital Cost	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Ann. Cost	Operating Cost	COE	PV Production	Grid Purchases	Grid Sales	Grid Net Purchases	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Excess Electricity	Battery Autonomy	Battery Throughput
	$/kWh	$/kWh	$/yr	kW	kW	kWh	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	%	kWh/yr	hr	kWh/yr
2014	0.061	0.069	105	1,000	0	0	0	0	406,633	0	0	43,087	0	43,087	43,087	0.064	0	670,503	0	670,503	670,503	670,504	0	0	0	0
2016	0.065	0.073	111	1,000	0	0	0	0	459,545	0	0	45,652	0	45,652	45,652	0.068	0	670,503	0	670,503	670,503	670,504	0	0	0	0
2018	0.069	0.077	118	1,000	50	0	0	79,000	689,109	5,549	0	42,856	0	48,405	42,856	0.072	77,575	592,928	0	592,928	670,503	670,504	0.12	0	0	0
2020	0.073	0.082	125	1,000	100	0	0	143,000	741,343	9,545	0	39,937	0	49,482	39,937	0.074	155,150	520,663	0	520,663	675,813	670,504	0.22	5,310	0	0
2022	0.077	0.087	133	1,000	125	0	0	165,000	765,501	11,013	0	40,081	0	51,095	40,081	0.076	193,938	492,670	0	492,670	686,608	670,504	0.27	16,104	0	0
2024	0.082	0.093	141	1,000	125	0	0	153,750	790,822	10,262	0	42,522	0	52,785	42,522	0.079	193,938	492,670	0	492,670	686,608	670,504	0.27	16,104	0	0
2026	0.087	0.098	150	1,000	125	0	0	147,500	823,369	9,845	0	45,112	0	54,957	45,112	0.082	193,938	492,670	0	492,670	686,608	670,504	0.27	16,104	0	0
2028	0.092	0.104	159	1,000	150	0	0	174,000	860,405	11,614	0	45,815	0	57,429	45,815	0.086	232,726	471,741	0	471,741	704,467	670,504	0.3	33,963	0	0
2030	0.098	0.11	169	1,000	150	0	0	169,500	897,707	11,314	0	48,605	0	59,919	48,605	0.089	232,726	471,741	0	471,741	704,467	670,504	0.3	33,963	0	0
2032	0.104	0.117	179	1,000	150	0	0	169,500	942,055	11,314	0	51,565	0	62,879	51,565	0.094	232,726	471,741	0	471,741	704,467	670,504	0.3	33,963	0	0
2034	0.11	0.124	190	1,000	175	100	25	212,039	986,866	14,153	728	50,989	0	65,870	51,717	0.098	271,513	437,834	0	437,834	709,347	670,504	0.35	33,568	1.05	19,891
2036	0.117	0.132	201	1,000	200	150	25	244,190	1,030,571	16,299	1,019	51,470	0	68,787	52,488	0.103	310,301	415,771	0	415,771	726,072	670,504	0.38	47,559	1.57	30,186
2038	0.124	0.14	214	139	250	450	75	343,101	1,072,422	22,901	2,976	45,703	0	71,581	48,680	0.107	387,876	342,702	0	342,702	730,578	670,501	0.49	36,342	4.7	89,482
2040	0.131	0.148	227	134	300	700	100	428,632	1,105,336	28,610	4,475	40,693	0	73,777	45,168	0.11	465,452	282,932	0	282,932	748,384	670,460	0.58	40,931	7.32	139,459
2042	0.139	0.158	240	130	350	1,000	150	524,600	1,129,201	35,015	6,378	33,977	0	75,370	40,355	0.112	543,025	216,440	0	216,440	759,465	670,421	0.68	35,792	10.45	200,734
2044	0.148	0.167	255	123	450	1,475	200	690,763	1,139,417	46,106	9,234	20,712	0	76,052	29,946	0.113	698,176	112,538	0	112,538	810,714	670,353	0.83	61,434	15.42	297,482
2046	0.157	0.177	270	123	450	1,475	200	687,783	1,150,571	45,907	9,095	21,794	0	76,797	30,890	0.115	698,176	112,538	0	112,538	810,714	670,353	0.83	61,434	15.42	297,482
2048	0.167	0.188	287	122	475	1,550	200	716,041	1,157,201	47,793	9,271	20,175	0	77,239	29,446	0.115	736,964	95,991	0	95,991	832,955	670,336	0.86	79,848	16.2	311,982
2050	0.177	0.2	304	122	475	1,550	200	713,096	1,167,802	47,597	9,135	21,215	0	77,947	30,350	0.116	736,964	95,991	0	95,991	832,955	670,336	0.86	79,848	16.2	311,982

San Antonio, TX - Commercial - With Exports to Grid (Net Energy Metering)

Year	Winter Power Price	Summer Power Price	Fixed Charges	Grid	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Capital Cost	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Ann. Cost	Operating Cost	COE	PV Production	Grid Purchases	Grid Sales	Grid Net Purchases	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Excess Electricity	Battery Autonomy	Battery Throughput
	$/kWh	$/kWh	$/yr	kW	kW	kWh	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	%	kWh/yr	hr	kWh/yr
2014	0.061	0.069	105	1,000	0	0	0	0	406,633	0	0	43,087	0	43,087	43,087	0.064	0	670,503	0	670,503	670,503	670,504	0	0	0	0
2016	0.065	0.073	111	1,000	0	0	0	0	459,545	0	0	45,652	0	45,652	45,652	0.068	0	670,503	0	670,503	670,503	670,504	0	0	0	0
2018	0.069	0.077	118	1,000	400	0	0	632,000	686,375	44,394	0	3,819	0	48,213	3,819	0.048	620,602	388,410	338,508	49,902	1,009,011	670,504	0.62	0	0	0
2020	0.073	0.082	125	1,000	425	0	0	607,750	630,519	40,565	0	1,520	0	42,085	1,520	0.04	659,389	384,460	373,345	11,114	1,043,849	670,504	0.63	0	0	0
2022	0.077	0.087	133	1,000	425	0	0	561,000	585,156	37,445	0	1,612	0	39,057	1,612	0.037	659,389	384,460	373,345	11,114	1,043,849	670,504	0.63	0	0	0
2024	0.082	0.093	141	1,000	425	0	0	522,750	548,377	34,892	0	1,710	0	36,602	1,710	0.035	659,389	384,460	373,345	11,114	1,043,849	670,504	0.63	0	0	0
2026	0.087	0.098	150	1,000	425	0	0	501,500	528,687	33,473	0	1,815	0	35,288	1,815	0.034	659,389	384,460	373,345	11,114	1,043,849	670,504	0.63	0	0	0
2028	0.092	0.104	159	1,000	425	0	0	493,000	521,843	32,906	0	1,925	0	34,831	1,925	0.033	659,389	384,460	373,345	11,114	1,043,849	670,504	0.63	0	0	0
2030	0.098	0.11	169	1,000	425	0	0	480,250	510,850	32,055	0	2,042	0	34,097	2,042	0.033	659,389	384,460	373,345	11,114	1,043,849	670,504	0.63	0	0	0
2032	0.104	0.117	179	1,000	425	0	0	480,250	512,713	32,055	0	2,167	0	34,222	2,167	0.033	659,389	384,460	373,345	11,114	1,043,849	670,504	0.63	0	0	0
2034	0.11	0.124	190	1,000	425	0	0	476,000	510,440	31,771	0	2,299	0	34,070	2,299	0.033	659,389	384,460	373,345	11,114	1,043,849	670,504	0.63	0	0	0
2036	0.117	0.132	201	1,000	450	0	0	499,500	507,774	33,340	0	552	0	33,892	552	0.031	698,176	380,794	408,467	-27,673	1,078,970	670,504	0.65	0	0	0
2038	0.124	0.14	214	1,000	450	0	0	499,500	508,277	33,340	0	586	0	33,926	586	0.031	698,176	380,794	408,467	-27,673	1,078,970	670,504	0.65	0	0	0
2040	0.131	0.148	227	1,000	450	0	0	495,000	504,312	33,040	0	622	0	33,661	622	0.031	698,176	380,794	408,467	-27,673	1,078,970	670,504	0.65	0	0	0
2042	0.139	0.158	240	1,000	450	0	0	495,000	504,879	33,040	0	659	0	33,699	659	0.031	698,176	380,794	408,467	-27,673	1,078,970	670,504	0.65	0	0	0
2044	0.148	0.167	255	1,000	450	0	0	490,500	500,981	32,739	0	700	0	33,439	700	0.031	698,176	380,794	408,467	-27,673	1,078,970	670,504	0.65	0	0	0
2046	0.157	0.177	270	1,000	450	0	0	490,500	501,619	32,739	0	742	0	33,481	742	0.031	698,176	380,794	408,467	-27,673	1,078,970	670,504	0.65	0	0	0
2048	0.167	0.188	287	1,000	450	0	0	486,000	497,796	32,439	0	787	0	33,226	787	0.031	698,176	380,794	408,467	-27,673	1,078,970	670,504	0.65	0	0	0
2050	0.177	0.2	304	1,000	450	0	0	486,000	498,514	32,439	0	835	0	33,274	835	0.031	698,176	380,794	408,467	-27,673	1,078,970	670,504	0.65	0	0	0

COMMERCIAL TABLES - LOS ANGELES, CA

Los Angeles, CA - Commercial - Non-Grid Exporting System

Year	Winter Power Price	Winter Demand Rate	Summer Power Price	Summer Demand Rate	Fixed Charges	Grid	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Capital Cost	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Ann. Cost	Operating Cost	COE	PV Production	Grid Purchases	Grid Sales	Grid Net Purchases	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Excess Electricity	Battery Autonomy	Battery Throughput
	$/kWh	$/kW/mo.	$/kWh	$/kW/mo.	$/yr	kW	kW	kWh	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	%	kWh/yr	hr	kWh/yr
2014	0.067	7.091	0.084	24.819	1570	1,000	0	0	0	0	581,323	0	0	61,597	0	61,597	61,597	0.105	0	586,556	0	586,556	586,556	586,557	0	0	0	0
2016	0.072	7.523	0.089	26.33	1665	1,000	0	0	0	0	660,208	0	0	65,587	0	65,587	65,587	0.112	0	586,556	0	586,556	586,556	586,557	0	0	0	0
2018	0.076	7.981	0.095	27.934	1767	1,000	75	0	0	118,500	967,683	8,324	0	59,649	0	67,973	59,649	0.116	120,538	466,941	0	466,941	587,479	586,557	0.2	923	0	0
2020	0.081	8.467	0.101	29.635	1875	1,000	100	0	0	143,000	1,050,035	9,545	0	60,542	0	70,086	60,542	0.119	160,717	436,122	0	436,122	596,839	586,557	0.26	10,283	0	0
2022	0.085	8.983	0.107	31.44	1989	100	125	50	25	179,020	1,089,160	11,949	641	60,108	0	72,698	60,749	0.124	200,897	412,687	0	412,687	613,584	586,427	0.3	26,460	0.6	2,599
2024	0.091	9.53	0.113	33.354	2110	96	150	75	25	201,762	1,129,677	13,467	786	61,149	0	75,402	61,935	0.129	241,076	394,416	0	394,416	635,492	586,403	0.33	47,612	0.9	5,560
2026	0.096	10.11	0.12	35.386	2238	1,000	125	0	0	147,500	1,197,276	9,845	0	70,069	0	79,914	70,069	0.136	200,897	415,160	0	415,160	616,057	586,557	0.29	29,500	0	0
2028	0.102	10.726	0.127	37.541	2375	1,000	125	0	0	145,000	1,258,707	9,678	0	74,336	0	84,014	74,336	0.143	200,897	415,160	0	415,160	616,057	586,557	0.29	29,500	0	0
2030	0.108	11.379	0.135	39.827	2519	1,000	150	125	25	189,710	1,321,115	12,663	930	74,588	0	88,180	75,517	0.15	241,076	376,884	0	376,884	617,960	586,557	0.36	24,722	1.49	25,185
2032	0.115	12.072	0.143	42.252	2673	1,000	175	250	50	237,113	1,387,243	15,826	1,834	74,933	0	92,594	76,767	0.158	281,255	341,583	0	341,583	622,838	586,557	0.42	22,823	2.99	50,723
2034	0.122	12.807	0.152	44.826	2835	1,000	225	500	75	326,195	1,448,009	21,772	3,407	71,470	0	96,650	74,877	0.165	361,614	278,409	0	278,409	640,023	586,557	0.53	26,767	5.98	100,636
2036	0.129	13.587	0.161	47.555	3008	108	375	1,275	200	603,361	1,486,608	40,272	9,298	49,656	0	99,226	58,954	0.169	602,689	96,234	0	96,234	698,923	586,539	0.84	41,287	15.24	267,789
2038	0.137	14.415	0.171	50.452	3191	108	375	1,325	200	606,909	1,524,539	40,509	8,999	52,250	0	101,758	61,249	0.173	602,689	93,725	0	93,725	696,414	586,540	0.84	38,073	15.83	270,574
2040	0.145	15.293	0.182	53.524	3386	108	375	1,350	200	603,576	1,561,329	40,287	8,779	55,147	0	104,213	63,927	0.178	602,689	92,632	0	92,632	695,321	586,540	0.84	36,675	16.13	271,787
2042	0.154	16.224	0.193	56.784	3592	73	700	2,700	300	1,134,320	1,602,246	75,712	16,525	14,707	0	106,944	31,232	0.182	1,125,020	6,339	0	6,339	1,131,360	586,242	0.99	455,487	32.27	337,343
2044	0.164	17.212	0.205	60.242	3811	73	700	2,700	300	1,121,650	1,594,232	74,866	16,269	15,274	0	106,410	31,543	0.182	1,125,020	6,339	0	6,339	1,131,360	586,242	0.99	455,487	32.27	337,343
2046	0.174	18.26	0.217	63.91	4043	73	700	2,700	300	1,116,196	1,594,062	74,502	16,020	15,876	0	106,398	31,896	0.181	1,125,020	6,339	0	6,339	1,131,360	586,242	0.99	455,487	32.27	337,343
2048	0.184	19.372	0.23	67.803	4289	73	700	2,700	300	1,103,877	1,586,478	73,680	15,698	16,514	0	105,892	32,212	0.181	1,125,020	6,339	0	6,339	1,131,360	586,242	0.99	455,487	32.27	337,343
2050	0.195	20.552	0.244	71.932	4550	73	700	2,700	300	1,098,747	1,587,996	73,338	15,465	17,190	0	105,993	32,656	0.181	1,125,020	6,339	0	6,339	1,131,360	586,242	0.99	455,487	32.27	337,343

Los Angeles, CA - Commercial - With Exports to Grid (Net Energy Metering)

Year	Winter Power Price	Winter Demand Rate	Summer Power Price	Summer Demand Rate	Fixed Charges	Grid	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Capital Cost	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Ann. Cost	Operating Cost	COE	PV Production	Grid Purchases	Grid Sales	Grid Net Purchases	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Excess Electricity	Battery Autonomy	Battery Throughput
	$/kWh	$/kW/mo.	$/kWh	$/kW/mo.	$/yr	kW	kW	kWh	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	%	kWh/yr	hr	kWh/yr
2014	0.067	7.091	0.084	24.819	1570	1,000	0	0	0	0	581,323	0	0	61,597	0	61,597	61,597	0.105	0	586,556	0	586,556	586,556	586,557	0	0	0	0
2016	0.072	7.523	0.089	26.33	1665	1,000	0	0	0	0	660,208	0	0	65,587	0	65,587	65,587	0.112	0	586,556	0	586,556	586,556	586,557	0	0	0	0
2018	0.076	7.981	0.095	27.934	1767	1,000	350	0	0	553,000	880,366	38,844	0	22,995	0	61,840	22,995	0.068	562,510	341,096	317,050	24,046	903,606	586,557	0.62	0	0	0
2020	0.081	8.467	0.101	29.635	1875	1,000	350	0	0	500,500	865,995	33,407	0	24,396	0	57,802	24,396	0.064	562,510	341,096	317,050	24,046	903,606	586,557	0.62	0	0	0
2022	0.085	8.983	0.107	31.44	1989	1,000	350	0	0	462,000	849,754	30,837	0	25,881	0	56,718	25,881	0.063	562,510	341,096	317,050	24,046	903,606	586,557	0.62	0	0	0
2024	0.091	9.53	0.113	33.354	2110	1,000	375	0	0	461,250	838,781	30,787	0	25,199	0	55,986	25,199	0.06	602,689	337,597	353,731	-16,134	940,286	586,557	0.64	0	0	0
2026	0.096	10.11	0.12	35.386	2238	1,000	375	0	0	442,500	843,022	29,535	0	26,734	0	56,269	26,734	0.06	602,689	337,597	353,731	-16,134	940,286	586,557	0.64	0	0	0
2028	0.102	10.726	0.127	37.541	2375	1,000	375	0	0	435,000	859,914	29,035	0	28,362	0	57,396	28,362	0.061	602,689	337,597	353,731	-16,134	940,286	586,557	0.64	0	0	0
2030	0.108	11.379	0.135	39.827	2519	1,000	375	0	0	423,750	874,541	28,284	0	30,089	0	58,373	30,089	0.062	602,689	337,597	353,731	-16,134	940,286	586,557	0.64	0	0	0
2032	0.115	12.072	0.143	42.252	2673	1,000	375	0	0	423,750	901,995	28,284	0	31,921	0	60,205	31,921	0.064	602,689	337,597	353,731	-16,134	940,286	586,557	0.64	0	0	0
2034	0.122	12.807	0.152	44.826	2835	1,000	375	0	0	420,000	927,370	28,034	0	33,865	0	61,899	33,865	0.066	602,689	337,597	353,731	-16,134	940,286	586,557	0.64	0	0	0
2036	0.129	13.587	0.161	47.555	3008	1,000	375	0	0	416,250	954,518	27,783	0	35,928	0	63,711	35,928	0.068	602,689	337,597	353,731	-16,134	940,286	586,557	0.64	0	0	0
2038	0.137	14.415	0.171	50.452	3191	1,000	375	0	0	416,250	987,299	27,783	0	38,116	0	65,899	38,116	0.07	602,689	337,597	353,731	-16,134	940,286	586,557	0.64	0	0	0
2040	0.145	15.293	0.182	53.524	3386	1,000	375	0	0	412,500	1,018,326	27,533	0	40,437	0	67,970	40,437	0.072	602,689	337,597	353,731	-16,134	940,286	586,557	0.64	0	0	0
2042	0.154	16.224	0.193	56.784	3592	1,000	375	0	0	412,500	1,055,221	27,533	0	42,899	0	70,432	42,899	0.075	602,689	337,597	353,731	-16,134	940,286	586,557	0.64	0	0	0
2044	0.164	17.212	0.205	60.242	3811	1,000	375	0	0	408,750	1,090,612	27,283	0	45,512	0	72,795	45,512	0.077	602,689	337,597	353,731	-16,134	940,286	586,557	0.64	0	0	0
2046	0.174	18.26	0.217	63.91	4043	1,000	375	0	0	408,750	1,132,138	27,283	0	48,284	0	75,566	48,284	0.08	602,689	337,597	353,731	-16,134	940,286	586,557	0.64	0	0	0
2048	0.184	19.372	0.23	67.803	4289	1,000	375	0	0	405,000	1,172,442	27,032	0	51,224	0	78,257	51,224	0.083	602,689	337,597	353,731	-16,134	940,286	586,557	0.64	0	0	0
2050	0.195	20.552	0.244	71.932	4550	1,000	375	0	0	405,000	1,219,179	27,032	0	54,344	0	81,376	54,344	0.087	602,689	337,597	353,731	-16,134	940,286	586,557	0.64	0	0	0

COMMERCIAL TABLES - HONOLULU, HI

Honolulu, HI - Commercial - Non-Grid Exporting System

Year	Power Price	Demand Rate	Fixed Charges	Grid	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Capital Cost	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Ann. Cost	Operating Cost	COE	PV Production	Grid Purchases	Grid Sales	Grid Net Purchases	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Excess Electricity	Battery Autonomy	Battery Throughput
	$/kWh	$/kW/mo.	$/yr	kW	kW	kWh	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	%	kWh/yr	hr	kWh/yr
2014	0.397	10.845	484	124	450	1,475	200	1,129,675	2,034,571	119,700	25,183	70,699	0	215,582	95,882	0.281	718,912	129,692	44,427	85,265	848,604	722,666	83%	0	14.31	307,050
2016	0.421	11.505	513	122	500	1,725	225	1,095,409	1,904,829	108,820	22,931	57,479	0	189,230	80,410	0.238	798,791	88,056	72,639	15,417	886,846	722,659	89%	0	16.73	345,099
2018	0.446	12.206	544	120	550	1,775	225	1,386,198	2,470,711	97,371	23,492	52,688	0	173,550	76,179	0.203	878,669	70,134	131,238	-61,105	948,802	722,632	92%	0	17.22	357,810
2020	0.473	12.949	578	119	600	1,825	225	1,325,722	2,385,114	88,487	21,286	49,425	0	159,198	70,711	0.173	958,549	57,316	196,148	-138,832	1,015,865	722,628	94%	0	17.7	365,969
2022	0.502	13.738	613	116	650	1,875	250	1,287,500	2,268,025	85,936	19,525	45,922	0	151,383	65,447	0.154	1,038,429	46,071	262,865	-216,795	1,084,499	722,588	95%	0	18.19	373,389
2024	0.533	14.575	650	112	725	1,900	250	1,279,227	2,157,789	85,384	17,597	41,044	0	144,025	58,641	0.132	1,158,248	35,752	370,681	-334,930	1,193,999	722,541	97%	0	18.43	378,780
2026	0.565	15.462	690	112	725	1,900	250	1,204,103	2,089,221	80,370	15,766	43,312	0	139,448	59,079	0.128	1,158,248	35,752	370,681	-334,930	1,193,999	722,541	97%	0	18.43	378,780
2028	0.6	16.404	732	112	725	1,900	250	1,158,424	2,058,412	77,321	14,353	45,719	0	137,392	60,071	0.126	1,158,248	35,752	370,681	-334,930	1,193,999	722,541	97%	0	18.43	378,780
2030	0.636	17.403	776	105	750	2,150	275	1,176,512	2,022,913	78,528	14,923	41,571	0	135,023	56,494	0.12	1,198,187	26,858	399,561	-372,703	1,225,046	722,461	98%	0	20.85	386,859
2032	0.675	18.463	824	103	750	2,250	275	1,180,763	2,040,266	78,812	15,116	42,252	0	136,181	57,369	0.122	1,198,187	24,781	396,902	-372,121	1,222,969	722,430	98%	0	21.82	389,129
2034	0.716	19.587	874	52	850	3,700	300	1,470,443	2,023,843	98,147	23,511	13,427	0	135,085	36,938	0.108	1,357,947	2,746	529,540	-526,793	1,360,693	722,252	100%	0	35.89	407,758
2036	0.76	20.78	927	52	850	3,700	300	1,452,841	2,005,572	96,972	23,099	13,794	0	133,865	36,893	0.107	1,357,947	2,746	529,540	-526,793	1,360,693	722,252	100%	0	35.89	407,758
2038	0.806	22.046	983	52	850	3,700	300	1,444,886	1,998,028	96,441	22,737	14,183	0	133,362	36,920	0.107	1,357,947	2,746	529,540	-526,793	1,360,693	722,252	100%	0	35.89	407,758
2040	0.855	23.388	1043	52	850	3,700	300	1,428,912	1,983,184	95,375	22,399	14,596	0	132,371	36,996	0.106	1,357,947	2,746	529,540	-526,793	1,360,693	722,252	100%	0	35.89	407,758
2042	0.907	24.813	1107	52	850	3,700	300	1,420,920	1,976,319	94,842	22,036	15,035	0	131,913	37,071	0.105	1,357,947	2,746	529,540	-526,793	1,360,693	722,252	100%	0	35.89	407,758
2044	0.963	26.324	1174	52	850	3,700	300	1,404,650	1,961,758	93,756	21,685	15,500	0	130,941	37,185	0.105	1,357,947	2,746	529,540	-526,793	1,360,693	722,252	100%	0	35.89	407,758
2046	1.021	27.927	1246	52	850	3,700	300	1,397,176	1,956,570	93,257	21,345	15,993	0	130,594	37,338	0.104	1,357,947	2,746	529,540	-526,793	1,360,693	722,252	100%	0	35.89	407,758
2048	1.083	29.627	1322	52	850	3,700	300	1,381,387	1,942,467	92,203	20,934	16,516	0	129,653	37,450	0.104	1,357,947	2,746	529,540	-526,793	1,360,693	722,252	100%	0	35.89	407,758
2050	1.149	31.432	1402	52	850	3,700	300	1,374,357	1,938,969	91,734	20,615	17,071	0	129,420	37,686	0.103	1,357,947	2,746	529,540	-526,793	1,360,693	722,252	100%	0	35.89	407,758

Honolulu, HI - Commercial - With Exports to Grid (Net Energy Metering)

Year	Power Price	Demand Rate	Fixed Charges	Grid	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Capital Cost	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Ann. Cost	Operating Cost	COE	PV Production	Grid Purchases	Grid Sales	Grid Net Purchases	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Excess Electricity	Battery Autonomy	Battery Throughput
	$/kWh	$/kW/mo.	$/yr	kW	kW	kWh	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	%	kWh/yr	hr	kWh/yr
2014	0.397	10.845	484	1,000	450	0	0	670,500	843,423	71,046	0	18,323	0	89,369	18,323	0.079	718,912	406,455	402,666	3,788	1,125,366	722,700	0.64	0	0	0
2016	0.421	11.505	513	1,000	450	0	0	594,000	789,655	59,009	0	19,437	0	78,446	19,437	0.07	718,912	406,455	402,666	3,788	1,125,366	722,700	0.64	0	0	0
2018	0.446	12.206	544	1,000	450	0	0	711,000	1,004,560	49,943	0	20,621	0	70,563	20,621	0.063	718,912	406,455	402,666	3,788	1,125,366	722,700	0.64	0	0	0
2020	0.473	12.949	578	1,000	450	0	0	643,500	971,252	42,951	0	21,876	0	64,828	21,876	0.058	718,912	406,455	402,666	3,788	1,125,366	722,700	0.64	0	0	0
2022	0.502	13.738	613	1,000	450	0	0	594,000	941,712	39,647	0	23,209	0	62,856	23,209	0.056	718,912	406,455	402,666	3,788	1,125,366	722,700	0.64	0	0	0
2024	0.533	14.575	650	1,000	450	0	0	553,500	922,388	36,944	0	24,622	0	61,566	24,622	0.055	718,912	406,455	402,666	3,788	1,125,366	722,700	0.64	0	0	0
2026	0.565	15.462	690	1,000	475	0	0	560,500	919,763	37,411	0	23,980	0	61,391	23,980	0.053	758,851	402,672	438,823	-36,151	1,161,523	722,700	0.65	0	0	0
2028	0.6	16.404	732	1,000	475	0	0	551,000	932,142	36,777	0	25,440	0	62,217	25,440	0.054	758,851	402,672	438,823	-36,151	1,161,523	722,700	0.65	0	0	0
2030	0.636	17.403	776	1,000	475	0	0	536,750	941,104	35,826	0	26,989	0	62,816	26,989	0.054	758,851	402,672	438,823	-36,151	1,161,523	722,700	0.65	0	0	0
2032	0.675	18.463	824	1,000	475	0	0	536,750	965,729	35,826	0	28,633	0	64,459	28,633	0.055	758,851	402,672	438,823	-36,151	1,161,523	722,700	0.65	0	0	0
2034	0.716	19.587	874	1,000	475	0	0	532,000	987,104	35,509	0	30,377	0	65,886	30,377	0.057	758,851	402,672	438,823	-36,151	1,161,523	722,700	0.65	0	0	0
2036	0.76	20.78	927	1,000	475	0	0	527,250	1,010,070	35,192	0	32,227	0	67,419	32,227	0.058	758,851	402,672	438,823	-36,151	1,161,523	722,700	0.65	0	0	0
2038	0.806	22.046	983	1,000	475	0	0	527,250	1,039,473	35,192	0	34,189	0	69,381	34,189	0.06	758,851	402,672	438,823	-36,151	1,161,523	722,700	0.65	0	0	0
2040	0.855	23.388	1043	1,000	475	0	0	522,500	1,065,918	34,875	0	36,271	0	71,146	36,271	0.061	758,851	402,672	438,823	-36,151	1,161,523	722,700	0.65	0	0	0
2042	0.907	24.813	1107	1,000	475	0	0	522,500	1,099,012	34,875	0	38,480	0	73,355	38,480	0.063	758,851	402,672	438,823	-36,151	1,161,523	722,700	0.65	0	0	0
2044	0.963	26.324	1174	1,000	475	0	0	517,750	1,129,372	34,558	0	40,824	0	75,382	40,824	0.065	758,851	402,672	438,823	-36,151	1,161,523	722,700	0.65	0	0	0
2046	1.021	27.927	1246	1,000	475	0	0	517,750	1,166,620	34,558	0	43,310	0	77,868	43,310	0.067	758,851	402,672	438,823	-36,151	1,161,523	722,700	0.65	0	0	0
2048	1.083	29.627	1322	1,000	475	0	0	513,000	1,201,386	34,241	0	45,947	0	80,188	45,947	0.069	758,851	402,672	438,823	-36,151	1,161,523	722,700	0.65	0	0	0
2050	1.149	31.432	1402	1,000	475	0	0	513,000	1,243,308	34,241	0	48,746	0	82,987	48,746	0.071	758,851	402,672	438,823	-36,151	1,161,523	722,700	0.65	0	0	0

COMMERCIAL TABLES - ALL LOCATIONS

Financial Inputs for all Commercial Locations

Year	PV Capital Cost	PV Replacement Cost	Li-ion 1kWh Battery Capital Cost	Li-ion 1kWh Battery Replacement Cost	Converter Capital Cost	Converter Replacement Cost	Interest Rate
	$/Wdc	$/Wdc	$/kWh	$/kWh	$	$	%
2014	1.49	3.18	289.61	619.88	0.16	0.35	9.5
2016	1.32	2.85	234.15	506.05	0.14	0.31	8.7
2018	1.58	2.6	269.83	443.47	0.17	0.28	4.9
2020	1.43	2.37	236.56	391.23	0.16	0.26	4.4
2022	1.32	2.19	210.4	347.96	0.14	0.24	4.4
2024	1.23	2.03	186.83	308.99	0.13	0.22	4.4
2026	1.18	1.95	166.37	275.15	0.13	0.21	4.4
2028	1.16	1.91	149.96	248	0.13	0.21	4.4
2030	1.13	1.88	137.68	227.69	0.12	0.2	4.4
2032	1.13	1.86	133.45	220.7	0.12	0.2	4.4
2034	1.12	1.85	130.39	215.64	0.12	0.2	4.4
2036	1.11	1.84	127.93	211.58	0.12	0.2	4.4
2038	1.11	1.83	125.78	208.01	0.12	0.2	4.4
2040	1.1	1.82	123.76	204.68	0.12	0.2	4.4
2042	1.1	1.82	121.6	201.1	0.12	0.2	4.4
2044	1.09	1.81	119.5	197.64	0.12	0.2	4.4
2046	1.09	1.8	117.48	194.28	0.12	0.2	4.4
2048	1.08	1.79	115.51	191.04	0.12	0.19	4.4
2050	1.08	1.78	113.61	187.89	0.12	0.19	4.4

RESIDENTIAL TABLES - WESTCHESTER, NY

Westchester, NY - Residential - Non-Grid Exporting System

Year	Volumetric Power Price	Grid	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Capital Cost	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Grid Purchases	Grid Sales	Grid Net Purchases	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Excess Electricity	Battery Autonomy	Battery Throughput
	$/kWh	kW	kW	kWh	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	%	kWh/yr	hr	kWh/yr
2014	0.225	3.05	1	0	0	2,670	26,565	267	0	2,393	2,661	2,393	0.223	1,298	10,637	0	10,637	11,935	11,934	11%	1	0	0
2016	0.239	3.05	2	0	0	4,700	29,387	433	0	2,273	2,706	2,273	0.227	2,596	9,512	0	9,512	12,108	11,934	20%	173	0	0
2018	0.253	3.05	2	0	0	6,060	40,319	426	0	2,406	2,832	2,406	0.237	2,596	9,512	0	9,512	12,108	11,934	20%	173	0	0
2020	0.269	3.05	2	0	0	5,500	43,053	375	0	2,559	2,933	2,559	0.246	2,596	9,512	0	9,512	12,108	11,934	20%	173	0	0
2022	0.285	3	3	0	0	7,530	44,579	513	0	2,524	3,037	2,524	0.255	3,894	8,857	0	8,857	12,751	11,934	26%	817	0	0
2024	0.302	3	4	5	1	11,165	45,938	761	50	2,319	3,130	2,369	0.262	5,192	7,645	0	7,645	12,837	11,935	36%	667	2.94	890
2026	0.321	2.9	7	18	3	21,433	46,590	1,460	159	1,555	3,174	1,714	0.266	9,086	4,732	0	4,732	13,818	11,935	60%	1,005	10.57	3,314
2028	0.34	2.9	8	21	3	23,488	46,744	1,600	165	1,419	3,185	1,585	0.267	10,384	4,051	0	4,051	14,435	11,935	66%	1,468	12.33	3,894
2030	0.361	2.9	8	23	4	23,477	47,010	1,600	174	1,430	3,203	1,603	0.268	10,384	3,833	0	3,833	14,217	11,935	68%	1,187	13.51	4,135
2032	0.383	2.9	8	24	4	23,337	47,782	1,590	174	1,491	3,256	1,666	0.273	10,384	3,768	0	3,768	14,152	11,935	68%	1,104	14.09	4,207
2034	0.406	2.9	9	26	4	25,677	48,739	1,749	183	1,389	3,321	1,571	0.278	11,682	3,292	0	3,292	14,974	11,935	72%	1,825	15.27	4,585
2036	0.431	2.9	9	26	4	25,391	49,619	1,730	180	1,471	3,381	1,651	0.283	11,682	3,292	0	3,292	14,974	11,935	72%	1,825	15.27	4,585
2038	0.457	2.9	9	27	4	25,416	50,634	1,732	183	1,535	3,450	1,718	0.289	11,682	3,241	0	3,241	14,923	11,935	73%	1,760	15.86	4,641
2040	0.485	2.9	10	28	4	27,511	51,734	1,874	186	1,464	3,525	1,650	0.295	12,980	2,904	0	2,904	15,883	11,935	76%	2,656	16.44	4,885
2042	0.515	2.9	10	29	4	27,472	52,704	1,872	188	1,531	3,591	1,719	0.301	12,980	2,861	0	2,861	15,841	11,935	76%	2,601	17.03	4,932
2044	0.546	2.9	10	32	5	28,124	53,712	1,916	208	1,535	3,660	1,743	0.307	12,980	2,694	0	2,694	15,674	11,935	77%	2,387	18.79	5,117
2046	0.579	2.85	11	33	5	30,151	54,702	2,054	211	1,462	3,727	1,673	0.312	14,278	2,411	0	2,411	16,689	11,935	80%	3,350	19.38	5,316
2048	0.614	2.85	11	34	5	30,015	55,560	2,045	213	1,527	3,786	1,741	0.317	14,278	2,377	0	2,377	16,655	11,935	80%	3,306	19.97	5,354
2050	0.652	2.85	11	35	5	30,096	56,715	2,051	215	1,598	3,864	1,814	0.324	14,278	2,344	0	2,344	16,622	11,935	80%	3,264	20.55	5,391

Westchester, NY - Residential - With Exports to Grid (Net Energy Metering)

Year	Volumetric Power Price	Grid	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Capital Cost	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Grid Purchases	Grid Sales	Grid Net Purchases	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Excess Electricity	Battery Autonomy	Battery Throughput
	$/kWh	kW	kW	kWh	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	%	kWh/yr	hr	kWh/yr
2014	0.225	1000	9	0	0	24,030	24,600	2,407	0	57	2,464	57	0.129	11,682	7,425	7,171	254	19,106	11,935	61%	0	0	0
2016	0.239	1000	9	0	0	21,150	21,809	1,948	0	61	2,008	61	0.105	11,682	7,425	7,171	254	19,106	11,935	61%	0	0	0
2018	0.253	1000	9	0	0	27,270	28,184	1,916	0	64	1,980	64	0.104	11,682	7,425	7,171	254	19,106	11,935	61%	0	0	0
2020	0.269	1000	9	0	0	24,750	25,752	1,686	0	68	1,755	68	0.092	11,682	7,425	7,171	254	19,106	11,935	61%	0	0	0
2022	0.285	1000	9	0	0	22,590	23,652	1,539	0	72	1,612	72	0.084	11,682	7,425	7,171	254	19,106	11,935	61%	0	0	0
2024	0.302	1000	9	0	0	20,970	22,095	1,429	0	77	1,505	77	0.079	11,682	7,425	7,171	254	19,106	11,935	61%	0	0	0
2026	0.321	1000	9	0	0	20,070	21,266	1,367	0	81	1,449	81	0.076	11,682	7,425	7,171	254	19,106	11,935	61%	0	0	0
2028	0.34	1000	9	0	0	19,620	20,887	1,337	0	86	1,423	86	0.074	11,682	7,425	7,171	254	19,106	11,935	61%	0	0	0
2030	0.361	1000	9	0	0	19,260	20,605	1,312	0	92	1,404	92	0.073	11,682	7,425	7,171	254	19,106	11,935	61%	0	0	0
2032	0.383	1000	9	0	0	19,080	20,507	1,300	0	97	1,397	97	0.073	11,682	7,425	7,171	254	19,106	11,935	61%	0	0	0
2034	0.406	1000	9	0	0	18,990	20,503	1,294	0	103	1,397	103	0.073	11,682	7,425	7,171	254	19,106	11,935	61%	0	0	0
2036	0.431	1000	9	0	0	18,810	20,416	1,282	0	109	1,391	109	0.073	11,682	7,425	7,171	254	19,106	11,935	61%	0	0	0
2038	0.457	1000	9	0	0	18,720	20,423	1,275	0	116	1,391	116	0.073	11,682	7,425	7,171	254	19,106	11,935	61%	0	0	0
2040	0.485	1000	9	0	0	18,630	20,437	1,269	0	123	1,392	123	0.073	11,682	7,425	7,171	254	19,106	11,935	61%	0	0	0
2042	0.515	1000	9	0	0	18,540	20,459	1,263	0	131	1,394	131	0.073	11,682	7,425	7,171	254	19,106	11,935	61%	0	0	0
2044	0.546	1000	9	0	0	18,450	20,484	1,257	0	139	1,396	139	0.073	11,682	7,425	7,171	254	19,106	11,935	61%	0	0	0
2046	0.579	1000	10	0	0	20,400	20,400	1,390	0	0	1,390	0	0.069	12,980	7,306	8,351	-1,044	20,286	11,935	64%	0	0	0
2048	0.614	1000	10	0	0	20,200	20,200	1,376	0	0	1,376	0	0.068	12,980	7,306	8,351	-1,044	20,286	11,935	64%	0	0	0
2050	0.652	1000	10	0	0	20,200	20,200	1,376	0	0	1,376	0	0.068	12,980	7,306	8,351	-1,044	20,286	11,935	64%	0	0	0

RESIDENTIAL TABLES - LOUISVILLE, KY

Louisville, KY - Residential - Non-Grid Exporting System

Year	Volumetric Power Price	Grid	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Capital Cost	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Grid Purchases	Grid Sales	Grid Net Purchases	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Excess Electricity	Battery Autonomy	Battery Throughput
	$/kWh	kW	kW	kWh	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	%	kWh/yr	hr	kWh/yr
2014	0.093	3.65	0	0	0	0	11,928	0	0	1,195	1,195	1,195	0.093	0	12,846	0	12,846	12,846	12,846	0%	0	0	0
2016	0.099	3.65	0	0	0	0	13,811	0	0	1,272	1,272	1,272	0.099	0	12,846	0	12,846	12,846	12,846	0%	0	0	0
2018	0.105	3.65	0	0	0	0	19,203	0	0	1,349	1,349	1,349	0.105	0	12,846	0	12,846	12,846	12,846	0%	0	0	0
2020	0.111	3.65	0	0	0	0	20,928	0	0	1,426	1,426	1,426	0.111	0	12,846	0	12,846	12,846	12,846	0%	0	0	0
2022	0.118	3.65	0	0	0	0	22,248	0	0	1,516	1,516	1,516	0.118	0	12,846	0	12,846	12,846	12,846	0%	0	0	0
2024	0.125	3.55	1	0	0	2,330	23,409	159	0	1,436	1,595	1,436	0.124	1,359	11,490	0	11,490	12,848	12,847	11%	1	0	0
2026	0.133	3.45	2	0	0	4,460	24,521	304	0	1,367	1,671	1,367	0.13	2,718	10,277	0	10,277	12,995	12,847	20%	148	0	0
2028	0.141	3.45	2	0	0	4,360	25,627	297	0	1,449	1,746	1,449	0.136	2,718	10,277	0	10,277	12,995	12,847	20%	148	0	0
2030	0.15	3.45	2	0	0	4,280	26,905	292	0	1,542	1,833	1,542	0.143	2,718	10,277	0	10,277	12,995	12,847	20%	148	0	0
2032	0.159	3.45	2	0	0	4,240	28,222	289	0	1,634	1,923	1,634	0.15	2,718	10,277	0	10,277	12,995	12,847	20%	148	0	0
2034	0.169	3.45	2	0	0	4,220	29,711	288	0	1,737	2,024	1,737	0.158	2,718	10,277	0	10,277	12,995	12,847	20%	148	0	0
2036	0.179	3.45	2	0	0	4,180	31,179	285	0	1,840	2,124	1,840	0.165	2,718	10,277	0	10,277	12,995	12,847	20%	148	0	0
2038	0.19	3.4	3	0	0	6,240	32,743	425	0	1,806	2,231	1,806	0.174	4,077	9,504	0	9,504	13,581	12,847	26%	734	0	0
2040	0.201	3.4	3	0	0	6,210	34,248	423	0	1,910	2,333	1,910	0.182	4,077	9,504	0	9,504	13,581	12,847	26%	734	0	0
2042	0.214	3.35	4	5	1	9,506	35,993	648	35	1,770	2,452	1,805	0.191	5,436	8,225	0	8,225	13,661	12,847	36%	586	2.73	862
2044	0.227	3.35	4	5	1	9,448	37,498	644	34	1,877	2,555	1,911	0.199	5,436	8,225	0	8,225	13,661	12,847	36%	586	2.73	862
2046	0.24	3.2	6	13	2	15,286	38,835	1,041	83	1,521	2,646	1,605	0.206	8,154	6,230	0	6,230	14,384	12,847	52%	907	7.09	2,381
2048	0.255	3.15	7	19	3	18,550	39,753	1,264	121	1,324	2,709	1,445	0.211	9,513	5,044	0	5,044	14,557	12,847	61%	798	10.37	3,445
2050	0.271	3.05	8	22	3	21,074	40,731	1,436	134	1,205	2,775	1,339	0.216	10,872	4,284	0	4,284	15,156	12,847	67%	1,230	12	4,074

Louisville, KY - Residential - With Exports to Grid (Net Energy Metering)

Year	Volumetric Power Price	Grid	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Capital Cost	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Grid Purchases	Grid Sales	Grid Net Purchases	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Excess Electricity	Battery Autonomy	Battery Throughput
	$/kWh	kW	kW	kWh	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	%	kWh/yr	hr	kWh/yr
2014	0.093	1000	0	0	0	0	11,929	0	0	1,195	1,195	1,195	0.093	0	12,848	0	12,848	12,848	12,848	0%	0	0	0
2016	0.099	1000	0	0	0	0	13,813	0	0	1,272	1,272	1,272	0.099	0	12,848	0	12,848	12,848	12,848	0%	0	0	0
2018	0.105	1000	0	0	0	0	19,205	0	0	1,349	1,349	1,349	0.105	0	12,848	0	12,848	12,848	12,848	0%	0	0	0
2020	0.111	1000	0	0	0	0	20,931	0	0	1,426	1,426	1,426	0.111	0	12,848	0	12,848	12,848	12,848	0%	0	0	0
2022	0.118	1000	0	0	0	0	22,251	0	0	1,516	1,516	1,516	0.118	0	12,848	0	12,848	12,848	12,848	0%	0	0	0
2024	0.125	1000	9	0	0	20,970	22,102	1,429	0	77	1,506	77	0.075	12,231	7,799	7,182	617	20,030	12,848	61%	0	0	0
2026	0.133	1000	9	0	0	20,070	21,275	1,367	0	82	1,450	82	0.072	12,231	7,799	7,182	617	20,030	12,848	61%	0	0	0
2028	0.141	1000	9	0	0	19,620	20,897	1,337	0	87	1,424	87	0.071	12,231	7,799	7,182	617	20,030	12,848	61%	0	0	0
2030	0.15	1000	9	0	0	19,260	20,619	1,312	0	93	1,405	93	0.07	12,231	7,799	7,182	617	20,030	12,848	61%	0	0	0
2032	0.159	1000	9	0	0	19,080	20,520	1,300	0	98	1,398	98	0.07	12,231	7,799	7,182	617	20,030	12,848	61%	0	0	0
2034	0.169	1000	9	0	0	18,990	20,521	1,294	0	104	1,398	104	0.07	12,231	7,799	7,182	617	20,030	12,848	61%	0	0	0
2036	0.179	1000	9	0	0	18,810	20,431	1,282	0	110	1,392	110	0.069	12,231	7,799	7,182	617	20,030	12,848	61%	0	0	0
2038	0.19	1000	9	0	0	18,720	20,441	1,275	0	117	1,393	117	0.07	12,231	7,799	7,182	617	20,030	12,848	61%	0	0	0
2040	0.201	1000	9	0	0	18,630	20,451	1,269	0	124	1,393	124	0.07	12,231	7,799	7,182	617	20,030	12,848	61%	0	0	0
2042	0.214	1000	9	0	0	18,540	20,478	1,263	0	132	1,395	132	0.07	12,231	7,799	7,182	617	20,030	12,848	61%	0	0	0
2044	0.227	1000	10	0	0	20,500	20,500	1,397	0	0	1,397	0	0.066	13,590	7,667	8,409	-742	21,257	12,848	64%	0	0	0
2046	0.24	1000	10	0	0	20,400	20,400	1,390	0	0	1,390	0	0.065	13,590	7,667	8,409	-742	21,257	12,848	64%	0	0	0
2048	0.255	1000	10	0	0	20,200	20,200	1,376	0	0	1,376	0	0.065	13,590	7,667	8,409	-742	21,257	12,848	64%	0	0	0
2050	0.271	1000	10	0	0	20,200	20,200	1,376	0	0	1,376	0	0.065	13,590	7,667	8,409	-742	21,257	12,848	64%	0	0	0

RESIDENTIAL TABLES - SAN ANTONIO, TX

San Antonio, TX - Residential - Non-Grid Exporting System

Year	Volumetric Power Price	Grid	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Capital Cost	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Grid Purchases	Grid Sales	Grid Net Purchases	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Excess Electricity	Battery Autonomy	Battery Throughput
	$/kWh	kW	kW	kWh	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	%	kWh/yr	hr	kWh/yr
2014	0.098	5.5	0	0	0	0	14,924	0	0	1,495	1,495	1,495	0.098	0	15,253	0	15,253	15,253	15,253	0%	0	0	0
2016	0.104	5.5	0	0	0	0	17,152	0	0	1,579	1,579	1,579	0.104	0	15,253	0	15,253	15,253	15,253	0%	0	0	0
2018	0.11	5.5	0	0	0	0	23,854	0	0	1,676	1,676	1,676	0.11	0	15,253	0	15,253	15,253	15,253	0%	0	0	0
2020	0.117	5.5	0	0	0	0	26,090	0	0	1,778	1,778	1,778	0.117	0	15,253	0	15,253	15,253	15,253	0%	0	0	0
2022	0.124	5.45	2	0	0	5,020	27,327	342	0	1,520	1,862	1,520	0.122	3,103	12,293	0	12,293	15,396	15,253	19%	143	0	0
2024	0.131	5.45	2	0	0	4,660	28,326	318	0	1,612	1,930	1,612	0.127	3,103	12,293	0	12,293	15,396	15,253	19%	143	0	0
2026	0.139	5.45	2	0	0	4,460	29,567	304	0	1,711	2,015	1,711	0.132	3,103	12,293	0	12,293	15,396	15,253	19%	143	0	0
2028	0.148	5.45	2	0	0	4,360	30,996	297	0	1,815	2,112	1,815	0.138	3,103	12,293	0	12,293	15,396	15,253	19%	143	0	0
2030	0.157	5.4	3	0	0	6,420	32,377	437	0	1,769	2,206	1,769	0.145	4,655	11,292	0	11,292	15,946	15,253	26%	694	0	0
2032	0.166	5.4	3	0	0	6,360	33,898	433	0	1,876	2,310	1,876	0.151	4,655	11,292	0	11,292	15,946	15,253	26%	694	0	0
2034	0.176	5.4	3	0	0	6,330	35,545	431	0	1,991	2,422	1,991	0.159	4,655	11,292	0	11,292	15,946	15,253	26%	694	0	0
2036	0.187	5.4	3	0	0	6,270	37,264	427	0	2,112	2,539	2,112	0.166	4,655	11,292	0	11,292	15,946	15,253	26%	694	0	0
2038	0.198	5.4	4	5	1	9,630	38,988	656	36	1,964	2,656	2,000	0.174	6,206	9,851	0	9,851	16,057	15,253	35%	574	2.3	869
2040	0.21	5.4	5	7	1	12,053	40,651	821	47	1,902	2,770	1,949	0.182	7,758	8,970	0	8,970	16,727	15,253	41%	1,118	3.22	1,344
2042	0.223	5.35	7	19	3	19,021	41,744	1,296	126	1,423	2,844	1,548	0.186	10,861	6,200	0	6,200	17,060	15,252	59%	816	8.73	3,740
2044	0.237	5.35	8	23	3	21,726	42,730	1,480	146	1,286	2,911	1,431	0.191	12,412	5,232	0	5,232	17,644	15,253	66%	1,180	10.57	4,569
2046	0.251	5.35	9	28	4	24,840	43,600	1,692	177	1,101	2,971	1,278	0.195	13,964	4,158	0	4,158	18,122	15,253	73%	1,395	12.86	5,559
2048	0.267	5.35	9	28	4	24,569	44,227	1,674	175	1,165	3,013	1,339	0.198	13,964	4,158	0	4,158	18,122	15,253	73%	1,395	12.86	5,559
2050	0.283	5.35	9	28	4	24,481	45,094	1,668	172	1,232	3,072	1,404	0.201	13,964	4,158	0	4,158	18,122	15,253	73%	1,395	12.86	5,559

San Antonio, TX - Residential - With Exports to Grid (Net Energy Metering)

Year	Volumetric Power Price	Grid	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Capital Cost	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Grid Purchases	Grid Sales	Grid Net Purchases	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Excess Electricity	Battery Autonomy	Battery Throughput
	$/kWh	kW	kW	kWh	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	%	kWh/yr	hr	kWh/yr
2014	0.098	1000	0	0	0	0	14,928	0	0	1,495	1,495	1,495	0.098	0	15,257	0	15,257	15,257	15,257	0%	0	0	0
2016	0.104	1000	0	0	0	0	17,156	0	0	1,580	1,580	1,580	0.104	0	15,257	0	15,257	15,257	15,257	0%	0	0	0
2018	0.11	1000	0	0	0	0	23,860	0	0	1,676	1,676	1,676	0.11	0	15,257	0	15,257	15,257	15,257	0%	0	0	0
2020	0.117	1000	0	0	0	0	26,097	0	0	1,778	1,778	1,778	0.117	0	15,257	0	15,257	15,257	15,257	0%	0	0	0
2022	0.124	1000	9	0	0	22,590	24,937	1,539	0	160	1,699	160	0.073	13,964	9,172	7,879	1,293	23,136	15,257	60%	0	0	0
2024	0.131	1000	10	0	0	23,300	23,300	1,588	0	0	1,588	0	0.065	15,515	9,018	9,276	-258	24,533	15,257	63%	0	0	0
2026	0.139	1000	10	0	0	22,300	22,300	1,519	0	0	1,519	0	0.062	15,515	9,018	9,276	-258	24,533	15,257	63%	0	0	0
2028	0.148	1000	10	0	0	21,800	21,800	1,485	0	0	1,485	0	0.061	15,515	9,018	9,276	-258	24,533	15,257	63%	0	0	0
2030	0.157	1000	10	0	0	21,400	21,400	1,458	0	0	1,458	0	0.059	15,515	9,018	9,276	-258	24,533	15,257	63%	0	0	0
2032	0.166	1000	10	0	0	21,200	21,200	1,444	0	0	1,444	0	0.059	15,515	9,018	9,276	-258	24,533	15,257	63%	0	0	0
2034	0.176	1000	10	0	0	21,100	21,100	1,438	0	0	1,438	0	0.059	15,515	9,018	9,276	-258	24,533	15,257	63%	0	0	0
2036	0.187	1000	10	0	0	20,900	20,900	1,424	0	0	1,424	0	0.058	15,515	9,018	9,276	-258	24,533	15,257	63%	0	0	0
2038	0.198	1000	10	0	0	20,800	20,800	1,417	0	0	1,417	0	0.058	15,515	9,018	9,276	-258	24,533	15,257	63%	0	0	0
2040	0.21	1000	10	0	0	20,700	20,700	1,410	0	0	1,410	0	0.057	15,515	9,018	9,276	-258	24,533	15,257	63%	0	0	0
2042	0.223	1000	10	0	0	20,600	20,600	1,404	0	0	1,404	0	0.057	15,515	9,018	9,276	-258	24,533	15,257	63%	0	0	0
2044	0.237	1000	10	0	0	20,500	20,500	1,397	0	0	1,397	0	0.057	15,515	9,018	9,276	-258	24,533	15,257	63%	0	0	0
2046	0.251	1000	10	0	0	20,400	20,400	1,390	0	0	1,390	0	0.057	15,515	9,018	9,276	-258	24,533	15,257	63%	0	0	0
2048	0.267	1000	10	0	0	20,200	20,200	1,376	0	0	1,376	0	0.056	15,515	9,018	9,276	-258	24,533	15,257	63%	0	0	0
2050	0.283	1000	10	0	0	20,200	20,200	1,376	0	0	1,376	0	0.056	15,515	9,018	9,276	-258	24,533	15,257	63%	0	0	0

RESIDENTIAL TABLES - LOS ANGELES, CA

Los Angeles, CA - Residential - Non-Grid Exporting System

Year	Volumetric Power Price	Grid	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Capital Cost	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Grid Purchases	Grid Sales	Grid Net Purchases	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Excess Electricity	Battery Autonomy	Battery Throughput
	$/kWh	kW	kW	kWh	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	%	kWh/yr	hr	kWh/yr
2014	0.181	1.96	1	0	0	2,670	14,123	267	0	1,147	1,415	1,147	0.179	1,606	6,338	0	6,338	7,944	7,920	20%	23	0	0
2016	0.192	1.96	1	0	0	2,350	15,597	216	0	1,220	1,436	1,220	0.181	1,606	6,338	0	6,338	7,944	7,920	20%	23	0	0
2018	0.204	1.96	1	0	0	3,030	21,453	213	0	1,294	1,507	1,294	0.19	1,606	6,338	0	6,338	7,944	7,920	20%	23	0	0
2020	0.217	1.96	1	0	0	2,750	22,900	187	0	1,373	1,560	1,373	0.197	1,606	6,338	0	6,338	7,944	7,920	20%	23	0	0
2022	0.23	1.96	2	0	0	5,020	23,637	342	0	1,268	1,611	1,268	0.203	3,211	5,520	0	5,520	8,731	7,920	30%	811	0	0
2024	0.244	1.96	2	0	0	4,660	24,411	318	0	1,346	1,663	1,346	0.21	3,211	5,520	0	5,520	8,731	7,920	30%	811	0	0
2026	0.259	1.95	3	7	1	8,906	24,744	607	61	1,018	1,686	1,079	0.213	4,817	3,881	0	3,881	8,698	7,920	51%	403	6.19	1,410
2028	0.274	1.9	4	14	2	12,752	24,659	869	110	701	1,680	811	0.212	6,423	2,453	0	2,453	8,876	7,920	69%	226	12.39	2,752
2030	0.291	1.85	5	17	2	15,131	24,554	1,031	126	516	1,673	642	0.211	8,029	1,656	0	1,656	9,685	7,920	79%	843	15.04	3,471
2032	0.309	1.85	5	18	3	15,383	24,644	1,048	134	497	1,679	631	0.212	8,029	1,492	0	1,492	9,521	7,920	81%	631	15.93	3,653
2034	0.328	1.85	5	18	3	15,242	24,877	1,038	132	525	1,695	656	0.214	8,029	1,492	0	1,492	9,521	7,920	81%	631	15.93	3,653
2036	0.348	1.85	5	18	3	15,068	25,110	1,027	130	555	1,711	684	0.216	8,029	1,492	0	1,492	9,521	7,920	81%	631	15.93	3,653
2038	0.369	1.85	5	19	3	15,162	25,423	1,033	130	569	1,732	699	0.219	8,029	1,440	0	1,440	9,468	7,920	82%	564	16.81	3,711
2040	0.391	1.8	6	20	3	17,324	25,680	1,180	139	430	1,750	569	0.221	9,634	997	0	997	10,632	7,920	87%	1,628	17.7	4,083
2042	0.415	1.8	6	21	3	17,363	25,816	1,183	137	439	1,759	576	0.222	9,634	957	0	957	10,591	7,920	88%	1,577	18.58	4,128
2044	0.44	1.8	6	21	3	17,230	26,009	1,174	135	463	1,772	598	0.224	9,634	957	0	957	10,591	7,920	88%	1,577	18.58	4,128
2046	0.467	1.8	6	21	3	17,100	26,227	1,165	133	489	1,787	622	0.226	9,634	957	0	957	10,591	7,920	88%	1,577	18.58	4,128
2048	0.496	1.8	6	21	3	16,912	26,412	1,152	131	516	1,800	647	0.227	9,634	957	0	957	10,591	7,920	88%	1,577	18.58	4,128
2050	0.526	1.8	6	21	3	16,846	26,743	1,148	129	545	1,822	674	0.23	9,634	957	0	957	10,591	7,920	88%	1,577	18.58	4,128

Los Angeles, CA - Residential - With Exports to Grid (Net Energy Metering)

Year	Volumetric Power Price	Grid	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Capital Cost	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Grid Purchases	Grid Sales	Grid Net Purchases	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Excess Electricity	Battery Autonomy	Battery Throughput
	$/kWh	kW	kW	kWh	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	%	kWh/yr	hr	kWh/yr
2014	0.181	1000	5	0	0	13,350	13,350	1,337	0	0	1,337	0	0.104	8,029	4,784	4,892	-108	12,813	7,921	63%	0	0	0
2016	0.192	1000	5	0	0	11,750	11,750	1,082	0	0	1,082	0	0.084	8,029	4,784	4,892	-108	12,813	7,921	63%	0	0	0
2018	0.204	1000	5	0	0	15,150	15,150	1,064	0	0	1,064	0	0.083	8,029	4,784	4,892	-108	12,813	7,921	63%	0	0	0
2020	0.217	1000	5	0	0	13,750	13,750	937	0	0	937	0	0.073	8,029	4,784	4,892	-108	12,813	7,921	63%	0	0	0
2022	0.23	1000	5	0	0	12,550	12,550	855	0	0	855	0	0.067	8,029	4,784	4,892	-108	12,813	7,921	63%	0	0	0
2024	0.244	1000	5	0	0	11,650	11,650	794	0	0	794	0	0.062	8,029	4,784	4,892	-108	12,813	7,921	63%	0	0	0
2026	0.259	1000	5	0	0	11,150	11,150	760	0	0	760	0	0.059	8,029	4,784	4,892	-108	12,813	7,921	63%	0	0	0
2028	0.274	1000	5	0	0	10,900	10,900	743	0	0	743	0	0.058	8,029	4,784	4,892	-108	12,813	7,921	63%	0	0	0
2030	0.291	1000	5	0	0	10,700	10,700	729	0	0	729	0	0.057	8,029	4,784	4,892	-108	12,813	7,921	63%	0	0	0
2032	0.309	1000	5	0	0	10,600	10,600	722	0	0	722	0	0.056	8,029	4,784	4,892	-108	12,813	7,921	63%	0	0	0
2034	0.328	1000	5	0	0	10,550	10,550	719	0	0	719	0	0.056	8,029	4,784	4,892	-108	12,813	7,921	63%	0	0	0
2036	0.348	1000	5	0	0	10,450	10,450	712	0	0	712	0	0.056	8,029	4,784	4,892	-108	12,813	7,921	63%	0	0	0
2038	0.369	1000	5	0	0	10,400	10,400	709	0	0	709	0	0.055	8,029	4,784	4,892	-108	12,813	7,921	63%	0	0	0
2040	0.391	1000	5	0	0	10,350	10,350	705	0	0	705	0	0.055	8,029	4,784	4,892	-108	12,813	7,921	63%	0	0	0
2042	0.415	1000	5	0	0	10,300	10,300	702	0	0	702	0	0.055	8,029	4,784	4,892	-108	12,813	7,921	63%	0	0	0
2044	0.44	1000	5	0	0	10,250	10,250	698	0	0	698	0	0.055	8,029	4,784	4,892	-108	12,813	7,921	63%	0	0	0
2046	0.467	1000	5	0	0	10,200	10,200	695	0	0	695	0	0.054	8,029	4,784	4,892	-108	12,813	7,921	63%	0	0	0
2048	0.496	1000	5	0	0	10,100	10,100	688	0	0	688	0	0.054	8,029	4,784	4,892	-108	12,813	7,921	63%	0	0	0
2050	0.526	1000	5	0	0	10,100	10,100	688	0	0	688	0	0.054	8,029	4,784	4,892	-108	12,813	7,921	63%	0	0	0

RESIDENTIAL TABLES - HONOLULU, HI

Honolulu, HI - Residential - Non-Grid Exporting System																							
Year	Volumetric Power Price	Grid	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Capital Cost	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Grid Purchases	Grid Sales	Grid Net Purchases	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Excess Electricity	Battery Autonomy	Battery Throughput
	$/kWh	kW	kW	kWh	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	%	kWh/yr	hr	kWh/yr
2014	0.363	3.3	3	0	0	8,010	44,924	802	0	3,697	4,500	3,697	0.311	4,793	10,186	0	10,186	14,978	14,490	30%	488	0	0
2016	0.385	3.15	6	13	2	19,305	48,202	1,778	191	2,469	4,439	2,661	0.306	9,585	6,348	0	6,348	15,933	14,490	56%	746	6.29	2,630
2018	0.408	3.05	8	23	3	35,610	63,993	2,501	330	1,664	4,495	1,994	0.31	12,781	3,962	0	3,962	16,743	14,489	73%	992	11.13	4,755
2020	0.433	3.05	9	29	4	37,496	61,103	2,555	363	1,245	4,163	1,608	0.287	14,378	2,741	0	2,741	17,119	14,489	81%	1,058	14.03	5,925
2022	0.46	3	10	32	4	37,515	57,585	2,556	352	1,016	3,924	1,367	0.271	15,976	2,071	0	2,071	18,047	14,489	86%	1,828	15.48	6,519
2024	0.488	2.95	11	35	5	37,945	54,604	2,585	340	795	3,720	1,135	0.257	17,573	1,486	0	1,486	19,060	14,488	90%	2,703	16.93	7,042
2026	0.517	2.95	11	35	5	35,610	52,416	2,426	306	839	3,571	1,145	0.247	17,573	1,486	0	1,486	19,060	14,488	90%	2,703	16.93	7,042
2028	0.549	2.95	11	35	5	34,060	51,147	2,321	279	886	3,485	1,164	0.241	17,573	1,486	0	1,486	19,060	14,488	90%	2,703	16.93	7,042
2030	0.582	2.95	11	36	5	33,137	50,423	2,258	262	916	3,436	1,178	0.237	17,573	1,449	0	1,449	19,022	14,488	90%	2,655	17.41	7,083
2032	0.618	2.9	12	36	5	34,735	50,473	2,367	257	815	3,439	1,072	0.237	19,171	1,203	0	1,203	20,374	14,488	92%	3,965	17.41	7,245
2034	0.655	2.9	12	37	5	34,649	50,745	2,361	255	842	3,457	1,097	0.239	19,171	1,172	0	1,172	20,343	14,488	92%	3,924	17.9	7,280
2036	0.695	2.9	12	37	5	34,258	50,981	2,334	251	889	3,474	1,139	0.24	19,171	1,172	0	1,172	20,343	14,488	92%	3,924	17.9	7,280
2038	0.738	2.85	12	40	5	34,630	51,393	2,360	264	878	3,502	1,142	0.242	19,171	1,082	0	1,082	20,253	14,487	93%	3,812	19.35	7,379
2040	0.782	2.85	12	41	5	34,582	51,791	2,356	266	906	3,529	1,173	0.244	19,171	1,054	0	1,054	20,224	14,487	93%	3,776	19.83	7,410
2042	0.83	2.85	12	44	5	34,868	52,099	2,376	277	897	3,550	1,174	0.245	19,171	974	0	974	20,145	14,487	93%	3,675	21.28	7,498
2044	0.881	2.85	12	45	5	34,794	52,480	2,371	279	926	3,576	1,205	0.247	19,171	950	0	950	20,121	14,487	93%	3,645	21.77	7,525
2046	0.934	2.75	13	46	5	36,757	52,824	2,504	280	815	3,599	1,095	0.248	20,769	774	0	774	21,542	14,486	95%	5,042	22.25	7,622
2048	0.991	2.75	13	47	5	36,539	52,996	2,490	281	840	3,611	1,121	0.249	20,769	753	0	753	21,522	14,486	95%	5,016	22.74	7,645
2050	1.052	2.7	13	50	5	36,955	53,435	2,518	292	831	3,641	1,123	0.251	20,769	695	0	695	21,463	14,485	95%	4,944	24.19	7,709

Honolulu, HI - Residential - With Exports to Grid (Net Energy Metering)																							
Year	Volumetric Power Price	Grid	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Capital Cost	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Grid Purchases	Grid Sales	Grid Net Purchases	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Excess Electricity	Battery Autonomy	Battery Throughput
	$/kWh	kW	kW	kWh	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	%	kWh/yr	hr	kWh/yr
2014	0.363	1000	9	0	0	24,030	24,437	2,407	0	41	2,448	41	0.109	14,378	8,083	7,970	112	22,461	14,490	64%	0	0	0
2016	0.385	1000	9	0	0	21,150	21,619	1,948	0	43	1,991	43	0.089	14,378	8,083	7,970	112	22,461	14,490	64%	0	0	0
2018	0.408	1000	9	0	0	27,270	27,923	1,916	0	46	1,961	46	0.087	14,378	8,083	7,970	112	22,461	14,490	64%	0	0	0
2020	0.433	1000	9	0	0	24,750	25,464	1,686	0	49	1,735	49	0.077	14,378	8,083	7,970	112	22,461	14,490	64%	0	0	0
2022	0.46	1000	9	0	0	22,590	23,347	1,539	0	52	1,591	52	0.071	14,378	8,083	7,970	112	22,461	14,490	64%	0	0	0
2024	0.488	1000	9	0	0	20,970	21,773	1,429	0	55	1,484	55	0.066	14,378	8,083	7,970	112	22,461	14,490	64%	0	0	0
2026	0.517	1000	9	0	0	20,070	20,922	1,367	0	58	1,426	58	0.063	14,378	8,083	7,970	112	22,461	14,490	64%	0	0	0
2028	0.549	1000	9	0	0	19,620	20,524	1,337	0	62	1,398	62	0.062	14,378	8,083	7,970	112	22,461	14,490	64%	0	0	0
2030	0.582	1000	9	0	0	19,260	20,219	1,312	0	65	1,378	65	0.061	14,378	8,083	7,970	112	22,461	14,490	64%	0	0	0
2032	0.618	1000	9	0	0	19,080	20,098	1,300	0	69	1,369	69	0.061	14,378	8,083	7,970	112	22,461	14,490	64%	0	0	0
2034	0.655	1000	9	0	0	18,990	20,070	1,294	0	74	1,367	74	0.061	14,378	8,083	7,970	112	22,461	14,490	64%	0	0	0
2036	0.695	1000	9	0	0	18,810	19,955	1,282	0	78	1,360	78	0.061	14,378	8,083	7,970	112	22,461	14,490	64%	0	0	0
2038	0.738	1000	9	0	0	18,720	19,935	1,275	0	83	1,358	83	0.06	14,378	8,083	7,970	112	22,461	14,490	64%	0	0	0
2040	0.782	1000	9	0	0	18,630	19,919	1,269	0	88	1,357	88	0.06	14,378	8,083	7,970	112	22,461	14,490	64%	0	0	0
2042	0.83	1000	9	0	0	18,540	19,908	1,263	0	93	1,356	93	0.06	14,378	8,083	7,970	112	22,461	14,490	64%	0	0	0
2044	0.881	1000	9	0	0	18,450	19,901	1,257	0	99	1,356	99	0.06	14,378	8,083	7,970	112	22,461	14,490	64%	0	0	0
2046	0.934	1000	9	0	0	18,360	19,899	1,251	0	105	1,356	105	0.06	14,378	8,083	7,970	112	22,461	14,490	64%	0	0	0
2048	0.991	1000	9	0	0	18,180	19,813	1,239	0	111	1,350	111	0.06	14,378	8,083	7,970	112	22,461	14,490	64%	0	0	0
2050	1.052	1000	9	0	0	18,180	19,913	1,239	0	118	1,357	118	0.06	14,378	8,083	7,970	112	22,461	14,490	64%	0	0	0

RESIDENTIAL TABLES - ALL LOCATIONS

Financial Inputs for all Residential Locations							
Year	PV Capital Cost	PV Replacement Cost	Li-ion 1kWh Battery Capital Cost	Li-ion 1kWh Battery Replacement Cost	Converter Capital Cost	Converter Replacement Cost	Interest Rate
	$/Wdc	$/Wdc	$/kWh	$/kWh	$	$	%
2014	2.67	3.82	433.92	619.88	0.34	0.49	8.8
2016	2.35	3.35	354.23	506.05	0.3	0.43	7.8
2018	3.03	3.03	443.47	443.47	0.39	0.39	4.9
2020	2.75	2.75	391.23	391.23	0.35	0.35	4.6
2022	2.51	2.51	347.96	347.96	0.32	0.32	4.6
2024	2.33	2.33	308.99	308.99	0.3	0.3	4.6
2026	2.23	2.23	275.15	275.15	0.29	0.29	4.6
2028	2.18	2.18	248	248	0.28	0.28	4.6
2030	2.14	2.14	227.69	227.69	0.28	0.28	4.6
2032	2.12	2.12	220.7	220.7	0.27	0.27	4.6
2034	2.11	2.11	215.64	215.64	0.27	0.27	4.6
2036	2.09	2.09	211.58	211.58	0.27	0.27	4.6
2038	2.08	2.08	208.01	208.01	0.27	0.27	4.6
2040	2.07	2.07	204.68	204.68	0.27	0.27	4.6
2042	2.06	2.06	201.1	201.1	0.26	0.26	4.6
2044	2.05	2.05	197.64	197.64	0.26	0.26	4.6
2046	2.04	2.04	194.28	194.28	0.26	0.26	4.6
2048	2.02	2.02	191.04	191.04	0.26	0.26	4.6
2050	2.02	2.02	187.89	187.89	0.26	0.26	4.6

ENDNOTES

ENDNOTES

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