February 20, 2015

California Energy Commission
Dockets Office, MS-4 Docket No. 09-RENEW EO-01
1516 Ninth Street,
Sacramento, CA 95814-5512
docket@energy.ca.gov

RE: Desert Renewable Energy Conservation Plan DEIR/EIS (DRECP NEPA/CEQA)

Dear Decision-makers,

Preserve Wild Santee (PWS) has a keen interest in sustainable land use policies and has reviewed environmental documents for more than twenty years. Please consider the following comments upon the Desert Renewable Energy Conservation Plan DEIR/EIS.

Unreasonably Narrow Alternatives Undermine the Plan

The DRECP fails in its attempt to address the most important issue of our time – *climate change* – because the premise for the action proposed is unfounded. Distributed Energy Resources[1] (DERs) such as Distributed Generation (DG) and Energy Efficiency (EE) are primary keys to meeting demand for a clean energy economy. Yet the DRECP fails to include DER as an Alternative. The decision to include only utility preferred Alternatives based upon centralized power production that are tied to long transmission lines is unreasonable and contrary to CEQA and NEPA because it **omits information that would substantially change conclusions**. A DER Alternative must be included and should be established as the preferred alternative.

Flawed Rational for Rejecting a DG or Distributed Energy Resource Alternative

Papers cited at (II.8-7) to justify eliminating a DG Alternative from consideration are dated, contain invalid assumptions, are inaccurate and contain bias toward specific profit motives. Furthermore, "Barriers" suggested in (Russell and Weisman 2012) are technologically insignificant. For example, grid scale energy storage is now proven and available.

[1] Devi Glick, Matt Lehrman, and Owen Smith, *Rate Design for the Distribution Edge: Electricity Pricing for A Distributed Resource Future*, Rocky Mountain Institute, Report or White Paper, 2014, Table 2, Distributed Energy Resources (DERs), page 11. http://www.rmi.org/Knowledge-Center/Library/2014-25_eLab-RateDesignfortheDistributionEdge-Full-highres

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Other research documents the feasibility of DG and the ongoing transition of the entire U.S energy sector.[2] Amory B. Lovins, states, "this transition will require no technological miracles or social engineering – only the systematic application of many available straightforward techniques." [3]

The DEIR/EIS failed to consider research that projects **<u>centralized power plants and transmission lines will become obsolete due to market forces</u>**. Rocky Mountain Institute Research concludes:

> "The so-called utility death spiral is proving not just a hypothetical threat, but a real, near, and present one. The coming grid parity of solar-plus-battery systems in the foreseeable future, among other factors, signals the eventual demise of traditional utility business models…The "old" cost recovery model, based on kWh sales, by which utilities recover costs and an allowed market return on distribution networks, central power plants, and/or transmission lines will become obsolete. This is especially profound in certain regions of the country. In the Southwest across all MWh sold by utilities, for example, our conservative base case shows solar-plus-battery systems undercutting utility retail electricity prices for the most expensive one-fifth of load served in the year 2024; under more aggressive assumptions, off-grid systems prove cheaper than all utility sold electricity in the region just a decade out from today (see Figure ES3)."[4]

DER adoption is growing rapidly and is already responsible for exceeding 100% of the minimum load on many days in areas of adoption, such as Hawaii.

> "DPV adoption is concentrated in a handful of markets that offer a "postcard from the future" for the rest of the nation. In places where DPV adoption is high, such as Hawaii, rooftop solar may exceed 100% of minimum load on a circuit on many days. The rapid growth of solar adoption has also been astounding by all accounts. From 2009 to

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[2] Amory Lovins & Rocky Mountain Institute, Reinventing Fire: Bold Business Solutions for the New Energy Era, October 15, 2011. http://www.rmi.org/reinventingfire

[3] Amory B. Lovins, *A Farewell to Fossil Fuels*, Foregin Affairs, Vol. 91, No. 2, page 136. http://www.rmi.org/Knowledge-Center/Library/2012-01_FarewellToFossilFuels Also see the RMI Micropower Database 2014 (July) Guide. http://www.rmi.org/Knowledge-Center/Library/2014-18_MicropowerDatabase

[4] CohnReznick Think Energy and HOMER Energy, *The Economics of Grid Defection*, Rocky Mountain Institute, February 2014. http://www.rmi.org/Knowledge-Center/Library/RMIGridDefectionFull_2014-05

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> 2012, solar of all types grew 82% per year in the U.S., and is expected to continue growing at 28% annually during 2014–2016."[5]

California's solar resource potential is immense. California could generate enough rooftop PV to power itself.

> "California's solar resource has more than 17 million GWh of technical potential… California could theoretically power itself with just rooftop photovoltaics, which have a technical potential of 106,000 TWh."[6]

The DRECP's insistence on artificially considering and favoring only centralized power Alternatives will adversely impact both the economy and the environment. Consideration of market dynamics and distributed energy resource potential would significantly impact project objectives, goals and alter all project Alternatives that contain assumptions regarding the viability and need for centralized power. It is contrary to CEQA and NEPA to omit this information and fail to analyze it within a project Alternative.

Competing Plans Require Coordination

Approximately, half of the DRECP acreage is also the subject of the Western Mojave Plan (WEMO) revised FEIR/EIS (release imminent), yet there is not any coordination of the public comment periods and schedules for both plans so the implications can be considered and commented upon by the public. The comment period and schedule for the DRECP needs to be extended and adjusted accordingly.

Unresolved Issues

Funding sources within the implementation agreement are unclear, speculative or absent. How will lands within non-DFA areas be managed and how will the management be funded?

How do conservation elements of the plan meet the requirement for recovery of endangered species and what is the rationale for covered species (included and excluded)?

What lands within DFA's are actually available for development?

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[5] Devi Glick, Matt Lehrman, and Owen Smith, *Rate Design for the Distribution Edge: Electricity Pricing for A Distributed Resource Future*, Rocky Mountain Institute, Report or White Paper, 2014, page 14.
[6] *Reinventing Fire in Southern California: Distributed Resources and the San Onofre Outage*, RMI, 2012, page 9. http://www.rmi.org/Knowledge-Center/Library/2012-11_RFSoCal

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How are conflicts with local land use designation to be resolved?

Conclusion

The DRECP DEIR/EIS needs major revisions and recirculation as another draft available for public analysis.

Thank you for considering these comments,

Van K. Collinsworth
Resource Analyst/Executive Director

Attachments:
Overview of Distributed Energy Resources / PV (Excerpts) from *Reinventing Fire in Southern California: Distributed Resources and the San Onofre Outage*
The Economics of Grid Defection
A Farewell to Fossil Fuels

cc.
President Barack Obama
Governor Jerry Brown
Senator Barbara Boxer
Senator Diane Feinstein
San Diego County Board of Supervisors
SANDAG Chair Jack E. Dale
San Diego Mayor Kevin Faulkner
San Diego City Council
Santee City Council
Karen Douglas, CEC Commissioner
Sally Jewel, Secretary of the Interior
James G. Kenna, State Director BLM
Chris Beale, DRECP Acting Executive Director
Scott Flint, DRECP Program Manager California Energy Commission
Armand Gonzales, Special Advisor California Department of Fish and Wildlife
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Overview of Distributed Energy Resources

	SIZE OF RESOURCE	COST	TIME TO DEPLOY	PERSISTENCE
BEHAVIORAL SAVINGS	Small	Low	Fast	Low
DEMAND RESPONSE	Medium	Low-Medium	Fast	Medium-High
ENERGY EFFICIENCY	Medium	Low-Medium	Fast	Medium-High
SOLAR PV	Large	High	Medium-Fast	High
CHP/FUEL CELLS	Medium	Medium	Medium	High
STORAGE	Large	Very High	Slow	High

Figure 4: Overview of distributed energy resource opportunities in Southern California.

SOLAR PV

SIZE OF RESOURCE: LARGE| COST: HIGH | TIME TO DEPLOY: MEDIUM–FAST | PERSISTENCE: HIGH

Solar is an abundant resource in the region. California's solar resource has more than 17 million GWh of technical potential[27], with many of the best sites located in Southern California. Furthermore, while the potential for utility-scale solar is large, California could theoretically power itself with just rooftop photovoltaics, which have a technical potential of 106,000 TWh[28].

Just as important, the costs for solar photovoltaics continue to decline rapidly. Though many observers perceive solar as expensive, costs have decreased by more than 60% since 2000. Today, solar PV costs roughly $3.50 per watt (Wdc), though costs in Germany are much lower, around $2.00/Wdc. In other words, there are plenty of opportunities to reduce costs further. Streamlining the permitting and interconnection processes represents a large cost-reduction opportunity.

California also has set big goals for solar. California's goal 12,000 MW of locally sourced renewables by 2020, which will largely be solar, will require an annual growth rate of 15%. California's installed capacity already dwarfs the rest of the country – almost 1,300 MW, which is higher than the installed capacity in all other states combined[29].

To overcome Southern California's shortfall in capacity, however, solar will have to deploy more quickly and in the areas most needed. To do that, challenges associated with permitting, interconnection, and incentives will have to be addressed.

Cost trajectories for Solar PV

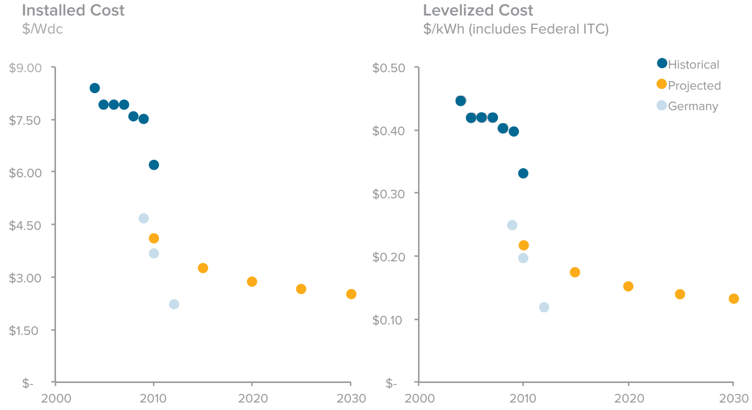

Figure 5. Costs projections for solar.
Source: Barbose, 2011; Black and Veatch, 2011.

[27]Lopez, U.S. Renewable Energy Technical Potentials.
[28]Lopez, U.S. Renewable Energy Technical Potentials.
[29]NREL, *Open PV Project.*

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THE ECONOMICS OF GRID DEFECTION

WHEN AND WHERE DISTRIBUTED SOLAR GENERATION PLUS STORAGE COMPETES WITH TRADITIONAL UTILITY SERVICE

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Founded in 2000, CohnReznick Think Energy, LLC is a full-service renewable energy consulting firm specializing in request for proposal (RFP) management, project development support, due diligence advisory, and energy purchasing services. CohnReznick Think Energy has assembled a team skilled in energy, economic, financial, and policy analysis; project management; engineering; technology and resource evaluation; and project development. The team has worked on more than 38 active solar projects representing over 500 MWs of capacity.

Since 1982, Rocky Mountain Institute has advanced market-based solutions that transform global energy use to create a clean, prosperous, and secure future. An independent, nonprofit think-and-do tank, RMI engages with businesses, communities, and institutions to accelerate and scale replicable solutions that drive the cost-effective shift from fossil fuels to efficiency and renewables.

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Matthias Vetter, Fraunhofer Institute
Ted Wiley, Aquion Energy

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Distributed electricity generation, especially solar PV, is rapidly spreading and getting much cheaper. Distributed electricity storage is doing the same, thanks largely to mass production of batteries for electric vehicles. Solar power is already starting to erode some utilities' sales and revenues. But what happens when solar and battery technologies are brought together? Together they can make the electric grid optional for many customers—without compromising reliability and increasingly at prices cheaper than utility retail electricity. Equipped with a solar-plus-battery system, customers can take or leave traditional utility service with what amounts to a "utility in a box."

This "utility in a box" represents a fundamentally different challenge for utilities. Whereas other technologies, including solar PV and other distributed resources without storage, net metering, and energy efficiency still require some degree of grid dependence, solar-plus-batteries enable customers to cut the cord to their utility entirely.

Notably, the point at which solar-plus-battery systems reach grid parity—already here in some areas and imminent in many others for millions of U.S. customers—is well within the 30-year planned economic life of central power plants and transmission infrastructure. Such parity and the customer defections it could trigger would strand those costly utility assets. Even before mass defection, a growing number of early adopters could trigger a spiral of falling sales and rising electricity prices that make defection via solar-plus-battery systems even more attractive and undermine utilities' traditional business models.

How soon could this happen? This analysis shows when and where U.S. customers could choose to bypass their utility without incurring higher costs or decreased reliability. It therefore maps how quickly different regions' utilities must change how they do business or risk losing it. New market realities are creating a profoundly different competitive landscape as both utilities and their regulators are challenged to adapt. Utilities thus must be a part of helping to design new business, revenue, and regulatory models.

Our analysis focuses on five representative U.S. geographies (NY, KY, TX, CA, and HI). Those geographies cover a range of solar resource potential, retail utility electricity prices, and solar PV penetration rates, considered across both commercial and residential regionally-specific load profiles. After considering many distributed energy technologies, we focus on solar-plus-battery systems because the technologies are increasingly cost effective, relatively mature, commercially available today, and can operate fully independent of the grid, thus embodying the greatest potential threat.

We model four possible scenarios:

1. Base case—Uses an average of generally accepted cost forecasts for solar and battery systems that can meet 100% of a building's load, in combination with occasional use of a diesel generator (for commercial systems only)
2. Accelerated technology improvement—Assumes that solar PV and battery technologies experience more aggressive cost declines, reaching or surpassing U.S. Department of Energy targets
3. Demand-side improvement—Includes investments in energy efficiency and user-controlled load flexibility
4. Combined improvement—Considers the combined effect of accelerated technology improvements and demand-side improvements

We compare our modeled scenarios against a reasonable range of retail electricity price forecasts bound by U.S. Energy Information Administration (EIA) forecasts on the low side and a 3%-real increase per year on the high side.

The analysis yields several important conclusions:

1. Solar-plus-battery grid parity is here already or coming soon for a rapidly growing minority of utility customers, raising the prospect of widespread grid defection. For certain customers, including many customer segments in Hawaii, grid parity is here today. It will likely be here before 2030 and potentially as early as 2020 for tens of millions of commercial and residential customers in additional geographies, including New York and California (see Figures 1 and 2). In general, grid parity arrives sooner for commercial than residential customers. Under more aggressive assumptions, such as accelerated technology improvements or investments in demand-side improvements, grid parity will arrive much sooner (see Figures 3 and 4).

2. Even before total grid defection becomes widely economic, utilities will see further kWh revenue decay from solar-plus-battery systems. Our analysis is based on average load profiles; in each geography there will be segments of the customer base for whom the economics improve much sooner. In addition,

FIGURE 1: OFF-GRID VS. UTILITY PRICE PROJECTIONS
COMMERCIAL - BASE CASE
[Y-AXIS 2012$/kWh]

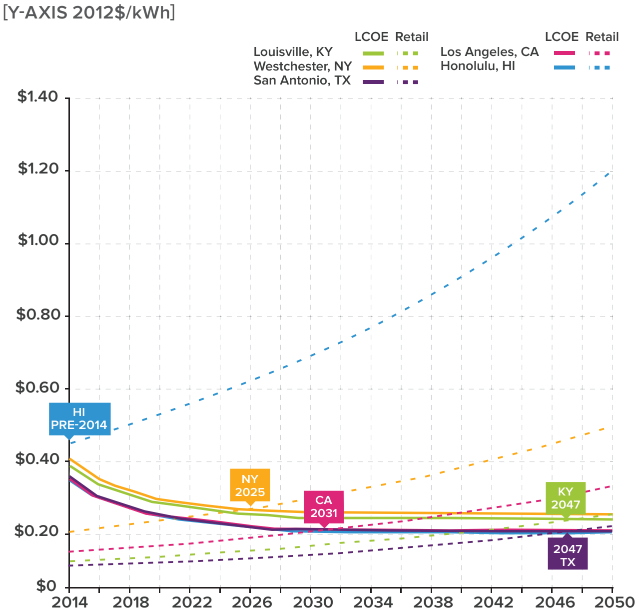


FIGURE 2: OFF-GRID VS. UTILITY PRICE PROJECTIONS
RESIDENTIAL - BASE CASE
[Y-AXIS 2012$/kWh]

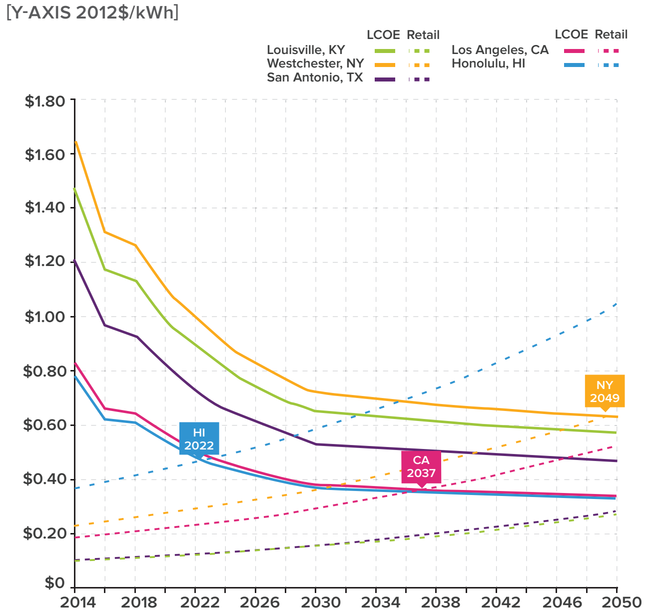


FIGURE 3: COMMERCIAL PARITY TIMELINE

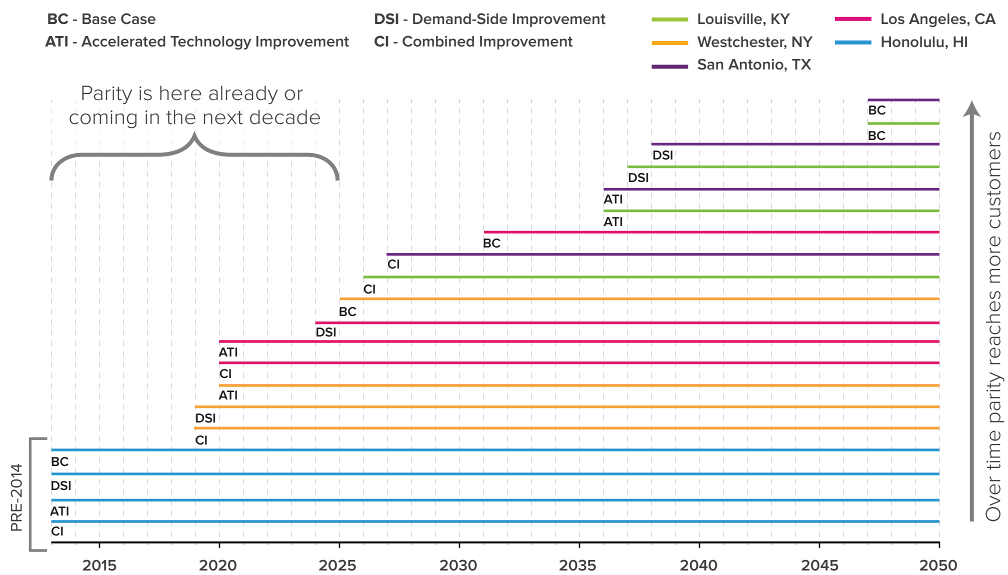
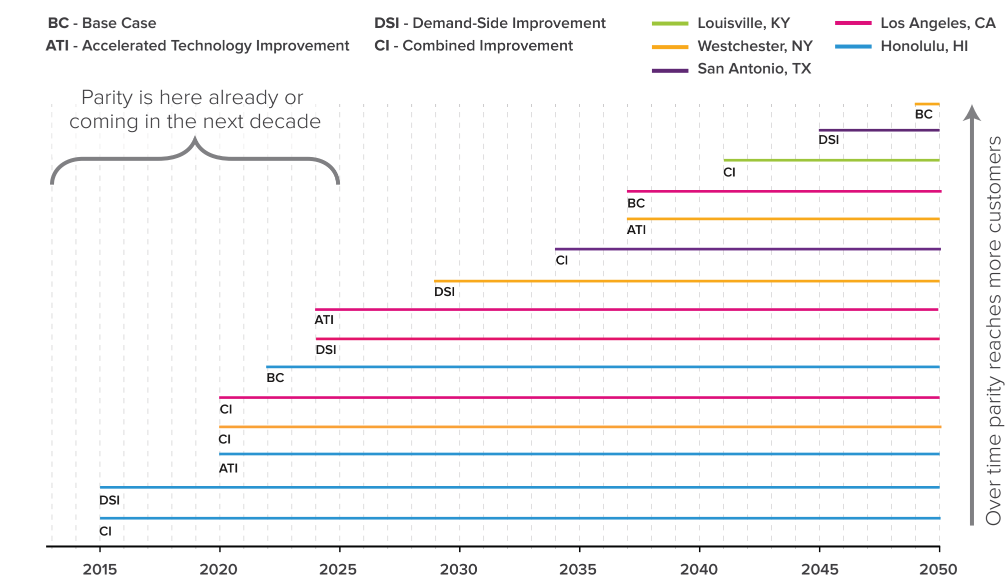


FIGURE 4: RESIDENTIAL PARITY TIMELINE

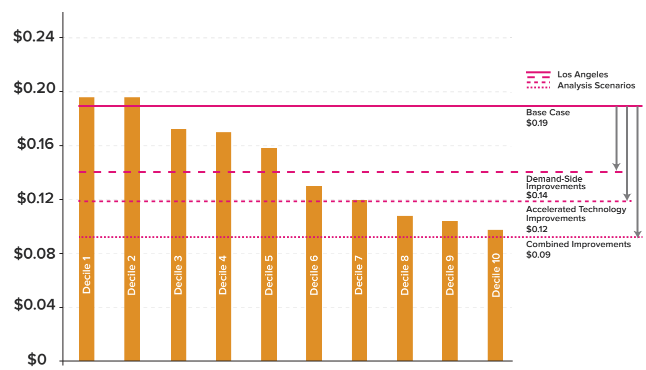


motivating factors such as customer desires for increased power reliability and low-carbon electricity generation are driving early adopters ahead of grid parity, including with smaller grid-dependent solar-plus-battery systems that can help reduce demand charges, provide backup power, and other benefits. Still others will look at investments in solar-plus-battery systems as part of an integrated package that includes efficiency and load flexibility. This early state could accelerate the infamous utility death spiral—self-reinforcing upward rate pressures, making further self-generation or total defection economic faster.

3. Because grid parity arrives within the 30-year economic life of typical utility power assets, it foretells the eventual demise of traditional utility business models. The “old” cost recovery model, based on kWh sales, by which utilities recover costs and an allowed market return on distribution networks, central power plants, and/or transmission lines will become obsolete. This is especially profound in certain regions of the country. In the Southwest across all MWh sold by utilities, for example, our conservative base case shows solar-plus-battery systems undercutting utility retail electricity prices for the most expensive one-fifth of load served in the year 2024; under more aggressive assumptions, off-grid systems prove cheaper than all utility-sold electricity in the region just a decade out from today (see Figure 5).

Though many utilities rightly see the impending arrival of solar-plus-battery grid parity as a threat, they could also see such systems as an opportunity to add value to the grid and their business models. The important next question is how utilities might adjust their existing business models or adopt new business models—either within existing regulatory frameworks or under an evolved regulatory landscape—to tap into and maximize new sources of value that build the best electricity system of the future at lowest cost to serve customers and society. These questions will be the subject of a forthcoming companion piece.

FIGURE 5: U.S. SOUTHWEST 2024 OFF-GRID COMMERCIAL SCENARIOS VS. ESTIMATED UTILITY DECILES
[Y-AXIS - 2012$/kWh]



States included in the Southwest region for this graph: AZ, CA, CO, NM, NV, UT

INTRODUCTION

01

INTRODUCTION

Utilities in the United States today face a variety of challenges to their traditional business models. An aging grid makes substantial investment in maintaining and modernizing system infrastructure a looming need. Meanwhile, myriad factors are making kWh sales decay a real concern, threatening the traditional mechanism by which regulated utilities recover costs and earn allowed market returns associated with infrastructure investment, as well as threatening the business model for all other types of utilities. These factors include:

- The falling costs and growing adoption of distributed generation (DG) and the prevalence of net-metering policies for integrating that DG
- Flat or even declining electricity demand, driven in part by increasing energy efficiency efforts as well as expanding demand-side strategies to manage electricity consumption

In addition, the electricity sector faces increasing social and regulatory pressures to reduce the carbon intensity and other environmental and health impacts of power generation.

Together, these forces undermine the "old" model of central power generation, transmission, and distribution. In particular, the combination of increasing costs and declining revenues creates upward price pressure. Yet higher retail electricity prices further prompt customers to invest in efficiency and distributed generation, creating a self-reinforcing cycle sometimes known as the utility death spiral (see Figure 6, page 12).

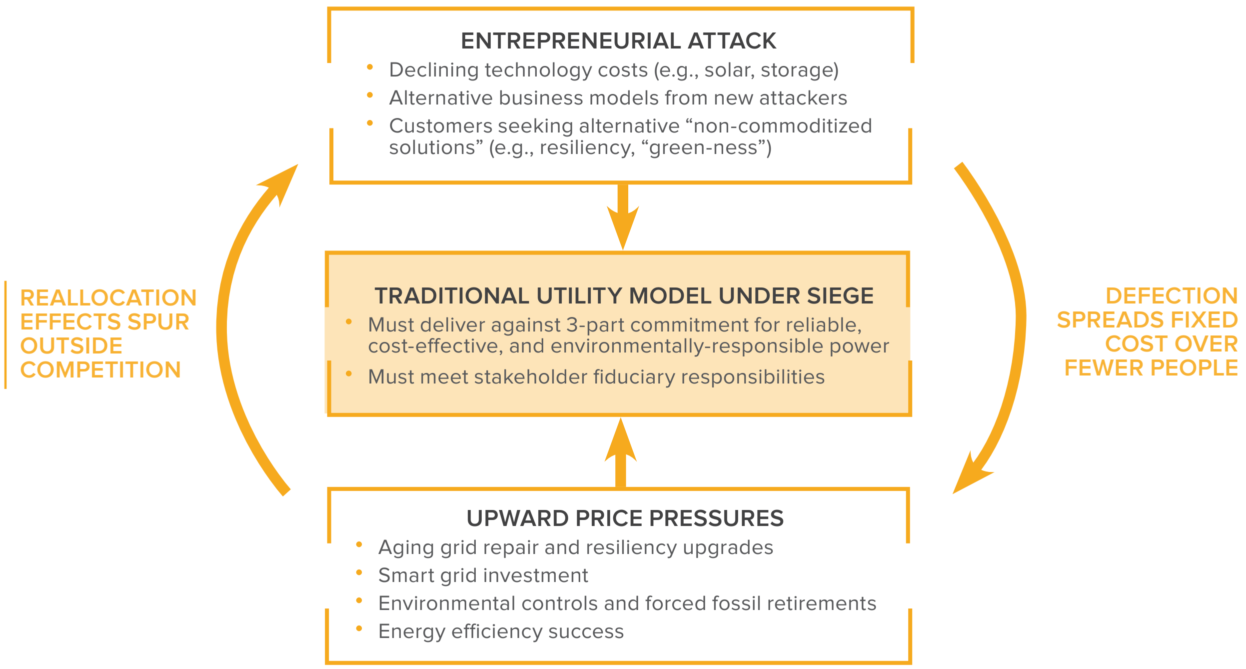
The idea of a utility death spiral, while not new, is increasingly relevant in its potential reality. Once upon a time, the utility death spiral was considered a potential outcome of efficiency. The growth of grid-connected distributed generation later added to death spiral concern. And while some customers have more choice than others, the trend of increasing options for electricity supply is likely here to stay. Now, there's also a fundamentally different growing threat and emerging opportunity wrapped up into one: combined distributed generation and energy storage. Other challenges, such as DG alone and energy efficiency, still maintain customers' grid dependence. Combined DG and storage, and in particular, solar-plus-battery systems, give a customer the option to go from grid connected to grid defected—customers could secede from the macro grid entirely.

Utilities have recently acknowledged this day could come. The Edison Electric Institute's January 2013 report, *Disruptive Challenges*,[1] noted:

> Due to the variable nature of renewables, there is a perception that customers will always need to remain on the grid. While we would expect customers to remain on the grid until a fully viable and economic distributed non-variable resource is available, one can imagine a day when battery storage technology or micro turbines could allow customers to be electric grid independent.

Two mutually reinforcing accelerants—declining costs for distributed energy technologies and increasing adoption of those technologies—are rapidly transforming the electricity market in ways that suggest grid parity (i.e., economic and technical service equality with the electrical grid) for solar-plus-battery systems is coming sooner than many had anticipated.

FIGURE 6: PRESSURE ON TRADITIONAL UTILITY BUSINESS MODELS



DECLINING COSTS FOR DISTRIBUTED ENERGY TECHNOLOGIES

Trends for Solar PV

The distributed U.S. solar industry has experienced robust growth in recent years, delivering an average annual installed capacity increase of 62% from 2010 to 2012.[2] Lower hardware costs (largely thanks to the collapse in PV module prices) and the rapid expansion of third-party financing for residential and commercial customers have fueled this growth.

We expect solar PV's levelized cost of energy (LCOE) to continue to decline through 2020 and beyond, despite both the likely end of the residential renewable energy tax credit and the reduction (from 30% to 10%) of the business energy investment tax credit in 2016. Further drops in upfront costs per installed Watt and additional improvements in solar PV finance (i.e., reduced cost of capital) will help drive the continued declines in solar PV's LCOE.

FIGURE 7: OPPORTUNITY SPECTRUM FOR ELECTRICITY END USERS

Trends for Battery Technology

Electric vehicle (EV) market growth has driven the lithium-ion (Li-ion) battery industry's recent expansion. Though it lags behind the growth of the solar PV market, it has still been significant in recent years. Coupled with greater opportunities for on-grid energy storage, including those enabled by regulations such as the Federal Energy Regulatory Commission's (FERC) Order 755 and California's AB 2514, battery demand is surging.[i] Opportunities in both the vehicle and grid markets will continue to drive the energy storage industry for the foreseeable future, yielding lower costs for batteries for mobile and stationary applications.

FIGURE 8: U.S. DISTRIBUTED PV INSTALLATIONS - ACTUAL AND PROJECTED[2]

[Y-AXIS ANNUAL INSTALLED CAPACITY - MW]

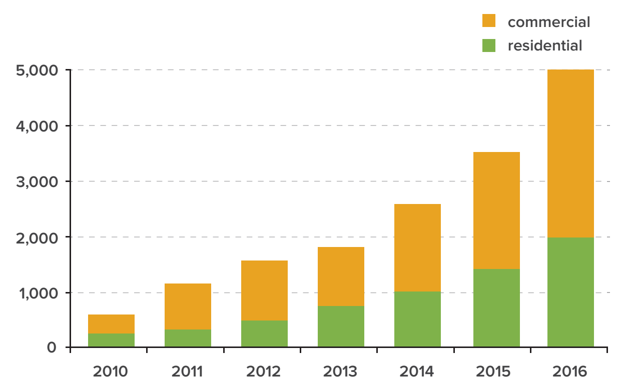


FIGURE 10: U.S. CUMULATIVE SALES OF PLUG-IN ELECTRIC VEHICLES[ii]

[Y-AXIS CUMULATIVE SALES BY MONTH]

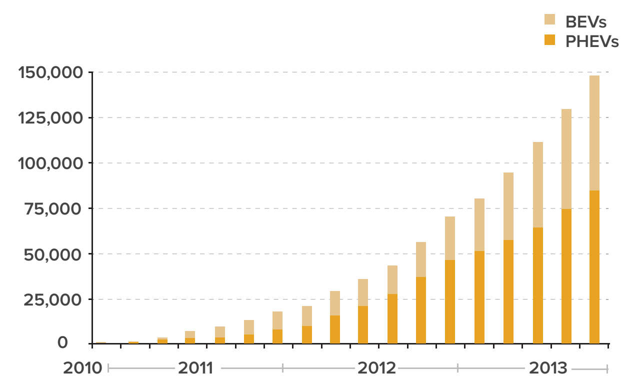


FIGURE 9: HISTORICAL PV PRICES[3]

[Y-AXIS 2012$/$W_{dc}$ - INSTALLED]

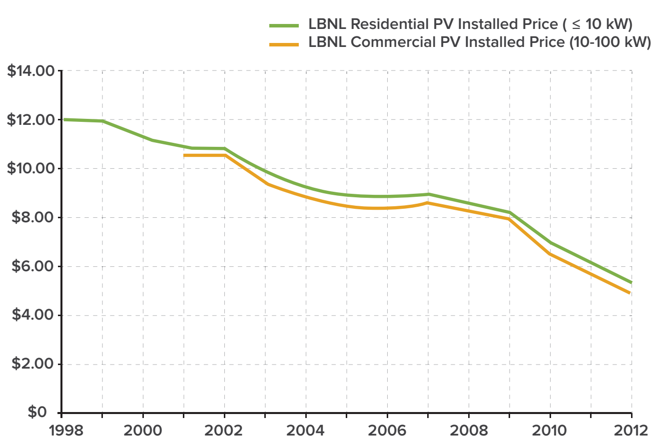
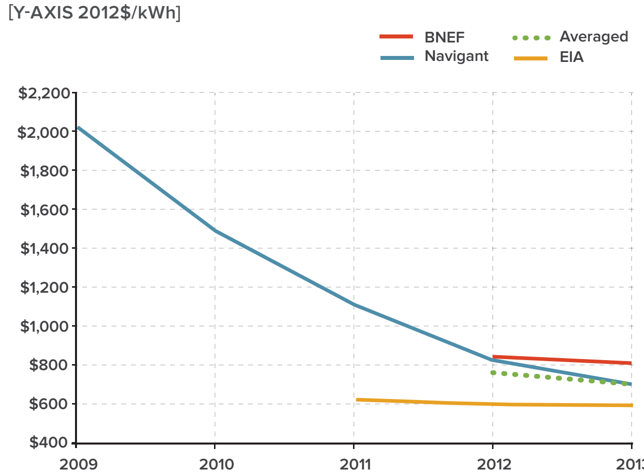


FIGURE 11: HISTORIC BATTERY PRICES

[Y-AXIS 2012$/kWh]



[i] FERC Order 755 mandates that frequency regulation resources are compensated for the actual quantity of regulation provided. This makes fast-ramping resources, such as batteries, more competitive in this service market. California AB 2514 requires the three investor-owned utilities in California (Pacific Gas & Electric, Southern California Edison, and San Diego Gas & Electric) to expand their electricity storage capacity and procure 1,325 MW of storage by 2020.

[ii] Historical cumulative sales trend of U.S. plug-in electric vehicles from December 2010 through August 2013. Based on data from the Electric Drive Transportation Association (http://electricdrive.org/index.php?ht=d%2Fsp%2Fi%2F20952%2Fpid%2F20952) and HybridCars.com (http://www.hybridcars.com/market-dashboard/). Accessed January 3, 2014. Adapted from Mario Roberto Duran Ortiz/Creative Commons (http://commons.wikimedia.org/wiki/File:US_PEV_Sales_2010_2013.png).

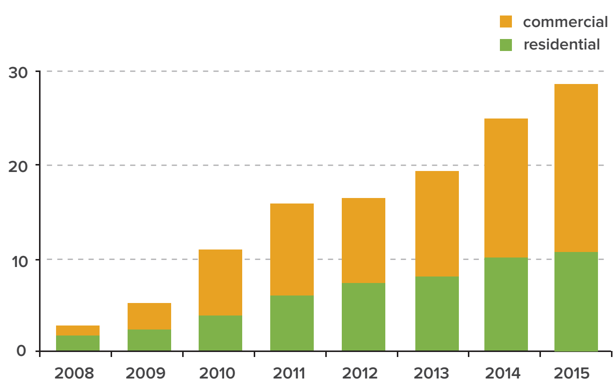
Support Technologies Unlock More Value

The evolution of support systems—including improved energy systems controls—is progressing apace. Synergistically, these controls have improved the value proposition of solar PV and batteries, thus creating further demand. In addition, smart inverters have seen price reductions and continue to offer new capabilities, unlocking new opportunities for their application and the increased integration of distributed energy resources.[4, iii]

Given the fast-moving technology landscape, we took a conservative view that represents steady progress and is aligned with published projections. However, with high innovation rates in solar, storage, and support technologies, it is conceivable that we under-estimate progress in our base case.

FIGURE 12: SOLAR INVERTER DEMAND BY SEGMENT[5, iv]

[Y-AXIS INSTALLED CAPACITY - GW_{AC}]



[iii] The trend in the market is towards intelligent inverters that are dynamic and reactive to the grid. Areas of development include dual on- and off-grid capability; the use of reactive power to control voltage being supplied to the grid; integrated storage; increased reliability, lifespan, and efficiency; and better data capture and display.

[iv] Bloomberg New Energy Finance central demand scenario for solar inverters. Categories are: residential 0–20 kW, commercial 20–1,000 kW. Figures given in AC assuming that AC capacity is approximately 85% of DC.

FORCES DRIVING ADOPTION OF OFF-GRID SYSTEMS

Based on our research and interviews with subject matter experts, we identified at least five forces driving the increased adoption of off-grid hybrid distributed generation and storage systems:

- Interest in reliability and resilience
- Demand for cleaner energy
- Pursuit of better economics
- Utility and grid frustration
- Regulatory changes

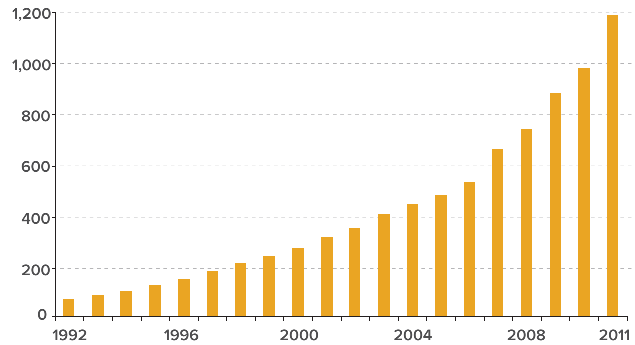
Interest in Reliability and Resilience

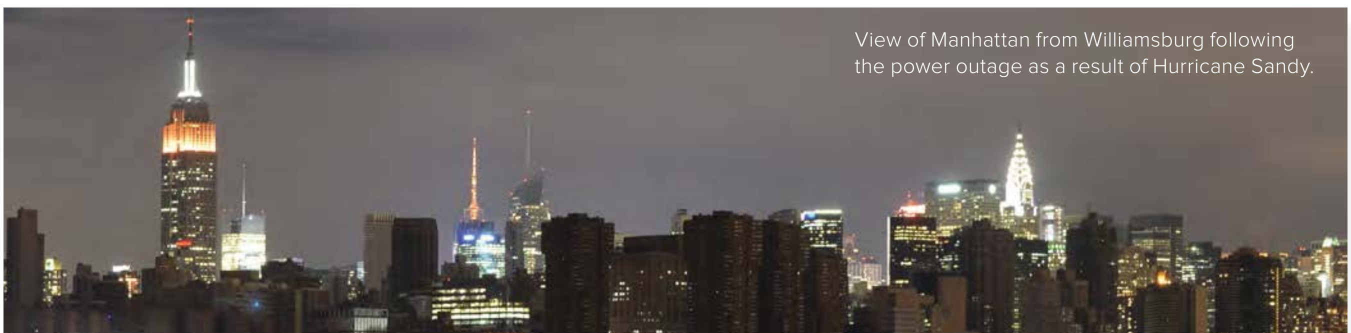
From severe weather events such as Superstorm Sandy, to direct physical attacks on grid infrastructure in Arkansas and Silicon Valley,[6] to reports on the potential for major system damage from geomagnetic storms, the fragility of the U.S. electric grid is now a nearly constant media topic.[7,8] As a byproduct of the U.S.'s early advance into the electrical age, our systems are among the oldest on the planet and experience triple the frequency disruptions and ten times the duration of system outages compared to some OECD peer nations such as Germany and Denmark.[9] In fact, in little over a decade, the U.S. has witnessed some of the most severe power outages in its history (see Table 1, page 14).

An increasingly popular solution to these reliability challenges is islandable microgrids, which produce and consume power locally in small, self-balancing networks capable of separating from and rejoining the larger grid on demand. They have a point of common coupling to the grid, and include both generation and loads that can be managed in a coordinated manner. Navigant Research forecasts the microgrid market to reach as high as $40 billion in the U.S. by 2020.[10]

A more extreme example of this trend, yet similarly connected to reliability and resilience interests, is permanently off-grid buildings. Prior to 2000 off-grid solar installations made up over 50% of solar PV projects. While currently a minute portion of total solar PV sales, such off-grid solar has actually continued its growth in absolute sales (see Figure 13). Though the majority of solar PV was off grid prior to 2000 primarily because it was used in remote locations where grid connection was a more difficult and expensive proposition, we're likely in the midst of a new era of off-grid solar PV (with batteries) within grid-accessible locations. The conversation has shifted from being off grid out of necessity to being off grid out of choice.

FIGURE 13: CUMULATIVE INSTALLED OFF-GRID PV IN SELECTED COUNTRIES[12]
[Y-AXIS MW]





View of Manhattan from Williamsburg following the power outage as a result of Hurricane Sandy.

DATE	EVENT	MAGNITUDE
October 2012	Superstorm Sandy	~8.2 million people in 17 states
June 2012	Derecho Summer Storm	~4.2 million customers across 11 Midwest and Mid-Atlantic states; widespread tree clearing and line restoration efforts in many cases took 7 to 10 days
October 2011	Nor'easter	~3 million customers in Mid-Atlantic and New England states; many lost power for more than 10 days
September 2011	Southwestern Blackout	~2.7 million customers across Arizona and Southern California lost power for 12 hours due to a technician's mistake during a high-load day
August 2011	Hurricane Irene	~5 million customers across the Mid-Atlantic and New England; outages lasted 2–6 days
February 2011	Rolling Blackouts in Texas	~1 million customers experiencing rolling blackouts due to forced outages at two major coal-fired power plants and high demand due to cold weather
February 2008	Florida Blackout	~4 million people lost power when a failed switch and fire at an electrical substation triggered widespread blackouts in Florida
August 2005	Hurricane Katrina	~2.6 million people across the Southeast lost power, although exact totals are hard to define, especially in Louisiana parishes that became unoccupied for months
August 2003	The Great Northeastern Blackout	~50 million people across eight states and Ontario lost power for up to four days after the mis-operation of the power transmission system

Table 1: Recent Major U.S. Blackouts[11, V]

[V] Major = those blackouts affecting 1 million or more people.

Demand for Cleaner Energy

Demand for cleaner energy with a lower carbon intensity and softer environmental footprint is on the rise.

On the commercial side, major corporations such as Walmart, Costco, IKEA, and Apple are increasingly "going solar."[13] According to the World Wildlife Fund's *Power Forward* report, nearly 60% of Fortune 100 and Global 100 companies have renewable energy targets, greenhouse gas emissions goals, or both.[14] These commitments are driving increased investment in renewable energy, including distributed solar PV. As of mid-2013, cumulative U.S. commercial solar installations totaled 3,380 MW, a 40% increase over the previous year.[15]

On the residential side, a 2012 survey of nearly 200 solar homeowners found that even if solar's economics weren't favorable, 1 in 4 would *still* have chosen to install a solar PV system because of their passion for the environment.[16] An earlier survey of more than 640 solar installs—primarily residential—found that reducing one's carbon footprint ranked nearly equal with reducing one's energy bill among the top reasons customers chose to go solar.[17] Small residential applications for completely off-grid homes have existed within the United States for many years. These homes and businesses were usually owned by the environmentally-driven consumer, as these buildings had to be energy sippers, because of the then-high cost of renewable energy technologies such as solar, wind, and storage.

Pursuit of Better Economics

Most remote locations without substantial energy infrastructure—like many islands—have been largely dependent on diesel fuel and diesel gensets[vi] to meet their electrical needs. In places such as Hawaii, Puerto Rico, Alaskan villages, and the U.S. Virgin Islands, expensive imported petroleum (e.g., diesel, fuel oil) provides 68–99% of electricity generation, resulting in retail electricity prices of $0.36–$0.50 per kWh or more.[18]

Thus on islands and anywhere with high retail electricity prices, there is a strong economic case for reducing the use of diesel fuel as a primary fuel source for electrical power, especially considering that the retail price of diesel in the U.S. has increased 233%-real in the past 15 years.[19]

Yet in 2013, liquid fuels were used for nearly 5% of global electricity production, accounting for 948 billion kilowatt-hours of generation, 387 GW of installed capacity, and nearly 5 million barrels/day of fuel consumption.[20,21] Further, projections from a new Navigant Research report suggest that annual installations of standby diesel generators will reach 82 GW per year by 2018,[22] signifying a growing opportunity for solar-plus-battery systems.

[vi] The term genset (generator set) is used throughout this analysis to refer to a diesel engine paired with electric generator.

Utility and Grid Frustration

While in the past the grid barely warranted a second thought for most people, sentiment is changing.[23, 24, 25] This change will only get worse as interconnection delays and red tape, arguments over net metering, and potentially rising prices continue to affect consumers. This reputational erosion poses additional challenges to utilities, above and beyond the increasingly competitive economics of off-grid solutions.

For example, in Hawaii, where utility interconnection limitations are making it impossible for many customers to take on grid-connected solar, off-grid development is increasing (see Hawaii call-out box on page 36). Similar desires from individuals for some semblance of energy independence—particularly the right to garner external financing for systems on their private property—led to an unlikely political alliance between conservatives and liberals in Georgia in 2012, as well as current, similarly across-the-aisle political activities in Arizona.[26]

Regulatory Changes

Rapid scaling of solar PV, and now grid-connected solar-plus-battery systems, are requiring federal, utility, state, and local regulators to explore new regulatory frameworks. Distributed generation and storage don't fit neatly into the traditional utility model of generation, distribution, and load or existing pricing structures that recover utilities' fixed costs through energy sales.

In California, where battery storage targets and incentives have made solar-plus-battery systems more attractive, utilities including Southern California Edison, PG&E, and Sempra Energy have made it challenging for system owners with storage to net meter their power.[27] The utilities expressed concern that customers could store grid electricity on their batteries and then sell it back to the grid at higher prices. This upset current customers who have had battery storage for some time and were surprised by the utilities' decisions. The matter impacts both California Public Utility Commission regulation as well as the state's Renewable Portfolio Standard.[28]

Perceived negative outcomes from regulation can drive customers, who desire solar PV and batteries for other factors, to pursue off-grid solutions.

In addition, incentives to promote storage could accelerate battery price declines, thereby increasing uptake of off-grid solutions. Several pro-storage regulations have recently been enacted (see box below). While they were primarily created with grid connectivity in mind, the overall development of the storage market and accompanying controls and other integration systems likely will lead to more robust and affordable off-grid storage applications.

FERC Orders 755 and 784: These orders opened the grid to storage by defining grid-level use and accounting for storage systems by favoring fast-reacting battery systems for frequency regulation and ancillary services. Grid operators thus gained a powerful tool to maintain power quality. While these tools are utility-scale now, these orders may someday be the foundation for residential-based frequency regulation and ancillary services provision.

AB 2514: California's legislature mandated an aggressive storage target of 1.3 GW by 2020. The bill includes a provision preventing utilities from owning more than 50% of statewide energy storage and allowing consumer-owned or -sited grid-connected storage to count toward the overall goal.

AB 327: This bill ensured that net metering will continue. Amendments to the bill eliminated the cap on the number of net-metered systems. The CA Public Utilities Commission (PUC) will now be tasked with determining how net metering is affecting the current rate model and how future rate-making policy will address reliability and freedom to generate electricity.

Self-Generation Incentive Program: California provides a subsidy for fuel cells, biogas digesters, and various forms of energy storage. A roughly $2.00/Watt credit for energy storage systems has created the initial momentum for integrated solar-plus-storage solutions.

ABOUT THIS STUDY

02

ABOUT THIS STUDY

PURPOSE

Until recently, solar-plus-battery systems were neither technically robust nor economically viable. But the dual trends of declining costs for distributed energy technologies and accelerating maturity and adoption rates of those technologies are changing that. In fact, recent media, market analysis, and industry discussions have suggested that low-cost solar-plus-battery combinations could enable total defection from the electric grid for a growing population of energy users. Yet, quantitative analysis supporting these claims has been limited.[vii] We sought to fill that gap, exploring a central fundamental question:

WHERE *AND* WHEN *WILL SOLAR-PLUS-BATTERY SYSTEMS REACH GRID PARITY IN THE U.S., ENABLING COST-EFFECTIVE CUSTOMER DEFECTION FROM UTILITIES?*

This report neither promotes nor discourages defection. It rather models current market trends and forecasts to identify where and when grid defection *could* happen, so that all stakeholders can consider its implications and plan a path forward accordingly.

[vii] Relevant studies include *Change and choice: The Future Grid Forum's analysis of Australia's potential electricity pathways to 2050*, by Australia's CSIRO Energy Flagship (https://publications.csiro.au/rpr/download?pid=csiro:EP1312486&dsid=DS13) and *Economic Policies for Using Storage to Enable Increased Renewable Energy Grid Integration*, by Japan's Research Institute of Economy, Trade & Industry (RIETI) (http://www.rieti.go.jp/jp/publications/dp/09j001.pdf).

[viii] Carbon considerations were based on the emissions of the system, not a full life-cycle assessment of the system's raw materials derivation, construction, use, and end-of-life dynamics. Low-to-no-carbon emission systems were desired due to assumptions of an increasingly carbon-constrained world, via regulations or other factors.

[ix] Batteries and solar are separately in wide use today, but not in combination in fully off-grid systems for developed world buildings with typical loads. However, considered separately (e.g., on-grid solar PV and lithium-ion battery packs for electric vehicles) their total implementation is over 400,000 in U.S. markets (~350,000 for distributed PV and ~70,000 EVs as of November 2013).

WHY SOLAR-PLUS-BATTERIES?

Our when-and-where question focused specifically on the combination of solar PV plus battery energy storage. We initially considered a range of possible technologies, but ultimately filtered our choices by several criteria. The chosen technology combination should be:

- Zero or very low carbon[viii]
- Commercially available[ix]
- Technologically advanced/mature
- Capable of full grid independence (no electric and natural gas connection required)

Solar-plus-battery quickly emerged as the most promising combination. In addition, the availability of product cost forecasts and technical analysis allowed us to make a reasonable cost and service comparison to retail electric service.

ANALYTICAL APPROACH

We conducted our analysis across five different locales (city or county). For each, we considered load profiles for both commercial and residential customers, a reasonable range of future utility retail price assumptions, and different scenarios that account for current solar-plus-battery cost trajectory forecasts as well as accelerated technology improvements and demand-side improvements (i.e., efficiency and user-controlled load flexibility) that could positively affect the economics of solar-plus-battery systems, potentially accelerating the timing of grid parity.

We analyzed potential off-grid solar-plus-battery operations, sizing, and economic value using the HOMER software, an energy system optimization tool designed to find the lowest-cost hybrid power system to meet an electrical demand. Varying the parameters and assumptions in the model can determine an optimal system configuration to meet specified performance requirements. 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. We used the HOMER model to determine NPC, LCOE, and annualized cost of energy for solar-plus-battery systems, which we compared to the same parameters for the same load serviced by the local electric utility.

Geographies

Our U.S.-specific analysis focused on five locations:

- Westchester County, New York[x]
- Louisville, Kentucky
- San Antonio, Texas
- Los Angeles County, California
- Honolulu, Hawaii

We chose these locations because they cover a representative range of conditions that influence grid parity, including annual solar resource potential, retail electricity prices, and currently installed distributed PV (see Figure 14).

Though not a primary driver of solar-plus-battery grid parity, the degree of utility regulation also varied. Three locations—Westchester County, NY, San Antonio, TX, and Los Angeles County, CA—are in significantly (NY and TX) or partially (CA) deregulated electricity markets.[xi] Two locations—Honolulu, HI, and Louisville, KY—are in regulated territories.

FIGURE 14: PROFILES OF GEOGRAPHIES

	WESTCHESTER, NY	LOUISVILLE, KY	SAN ANTONIO, TX	LOS ANGELES, CA	HONOLULU, HI
INSOLATION (kWh/m²/day)	4.5 kWh	4.5 kWh	6 kWh	6 kWh	5.5 kWh
2012 AVG RETAIL PRICE ($/kWh)	$0.15–$0.20	$0.06–$0.08	$0.05–$0.09	$0.09–$0.17	$0.34–$0.41
INSTALLED PV (MW)	122.02 MW	2.92 MW	131.16 MW	2074.53 MW	27.33 MW
MARKET STRUCTURE	Deregulated	Regulated	Deregulated	Deregulated	Regulated

[x] In metropolitan New York City area.
[XI] San Antonio is a vertically integrated municipal utility in a wholesale power region; Los Angeles has both a municipal and investor-owned utility, but uses the wholesale market for most generation.

BASE CASE

Load Profiles

We modeled both commercial and residential 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. For the base cases, we modeled both profiles with solar-plus-battery systems sized to meet 100% of annual demand, and for the commercial profiles, also a smaller solar-plus-battery system with a standby diesel generator.[xii] All scenarios were modeled to provide 100% load reliability during a typical meteorological year. Reliability metrics for off-grid systems are not perfectly transferable to grid reliability due to differences in system operations and the nature of the vulnerabilities that face each system.

Utility Retail Price Assumptions

Our modeling uses two projections—a lower and upper boundary—to create a 'wedge' of possible future utility electricity retail prices. Information from the U.S. EIA helped determine both boundaries. Note: these price assumptions do not take into account specific price structures in a region that can greatly influence the economics due to off-peak, mid-peak, and peak retail prices per kilowatt-hour.

The lower boundary uses EIA regional retail price projections extrapolated from 2012 to 2050 based on historical investment cycle averages. The upper boundary uses an annual price increase of 3%-real based on more recent capitalization trends. For the period 2004–2012, commercial and residential retail real (inflation-adjusted) prices annually rose an

FIGURE 15: STATE AVERAGE U.S. COMMERCIAL RETAIL RATES
[Y-AXIS ¢/kWh]

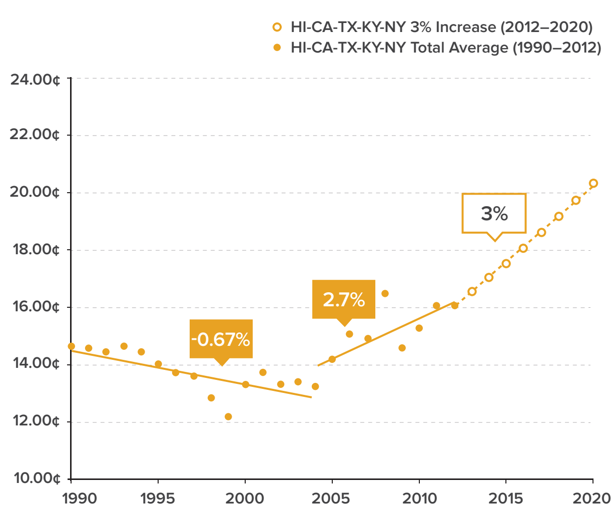
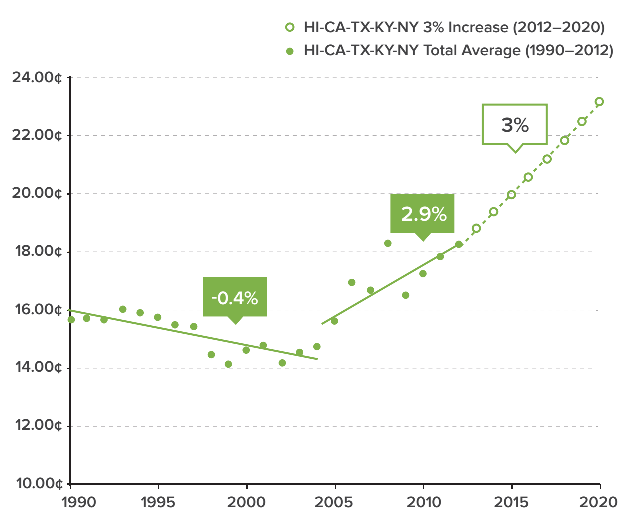


FIGURE 16: STATE AVERAGE U.S. RESIDENTIAL RETAIL RATES
[Y-AXIS ¢/kWh]



[xii] Diesel generators are much more common in commercial buildings compared to residential buildings, so we excluded them from our residential analysis.

average 2.7% and 2.9%, respectively, while rates in the geographies we looked at increased more than 3%-real during the period 2010–2012 (see Figures 15 and 16). Until such trends change, a 3%-real per year price increase should represent a reasonable upper boundary for our analysis.

There is significant evidence that similarly high rates of retail electricity price increases will continue. For instance, during the seven-year period 2005–2012, low and even negative load growth contributed to rising prices. During 2006–2010, annual average load growth across the U.S. was just 0.5%. Since 2010, it has been -0.7%. Such flat or declining load growth may well be the new norm. In addition, the 2012 Ceres report *Practicing Risk-Aware Electricity Regulation* noted that "if the U.S. utility industry adds $100 billion each year between 2010 and 2030"—based on the Brattle Group's estimate that simply maintaining the U.S. electric grid's aging infrastructure will require $2 trillion in investment over 20 years—"the net value of utility plant in service will grow [to]... a doubling of net invested capital.... This growth is considerably faster than the country has seen in many decades." This appears especially true in the near term as distributed energy and efficiency impacts and ongoing expenditures on grid reliability, modernization, and environmental controls put upward pressure on prices.

See Table 2 for a summary of lower and upper bound price projections for each geography's electric utility.[xiii]

UTILITY	LOAD PROFILE[29]	LOAD SIZE (kWh/YR)	LOWER PRICE PROJECTION[xiv, 30]	UPPER PRICE PROJECTION
Hawaiian Electric Co.	Honolulu Residential Honolulu Commercial	14,481 722,700	1.05% 0.85%	3%
Southern California Edison	Los Angeles County Residential Los Angeles County Commercial	7,914 586,557	0.10% 0.10%	
Louisville Gas & Electric	Louisville Residential Louisville Commercial	12,837 604,809	-0.50% -0.40%	
CPS Energy	San Antonio Residential San Antonio Commercial	15,247 670,504	0.90% 0.70%	
Con Edison (NY)	Westchester County Residential Westchester County Commercial	11,927 577,431	0.30% 0.10%	

Table 2: Electricity Retail Price Projections

[xiii] Additional information and background modeling assumptions can be found in Appendices A, B, C, and E.
[xiv] Since the Energy Information Administration does not provide a specific percentage change for Hawaii, rates were calculated from average diesel price projections given by the EIA (2011–2015).

Solar-Plus-Battery Base Case Assumptions

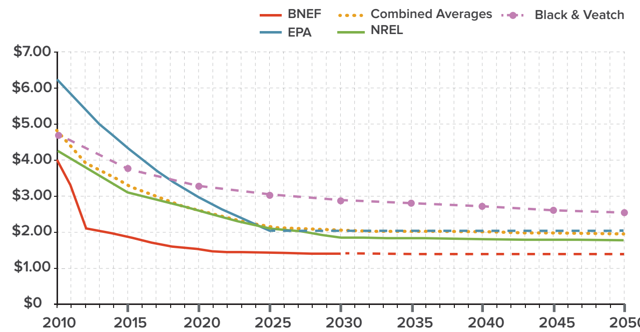
Our solar-plus-battery base case included projections for installed cost of solar PV systems, batteries, and cost of capital.[xv]

Solar PV

We undertook a thorough literature review to develop solar PV cost projections for customer-owned systems (vs. third-party arrangements) through 2050 (see Figures 17 and 18) and ultimately averaged four datasets:[xvi]

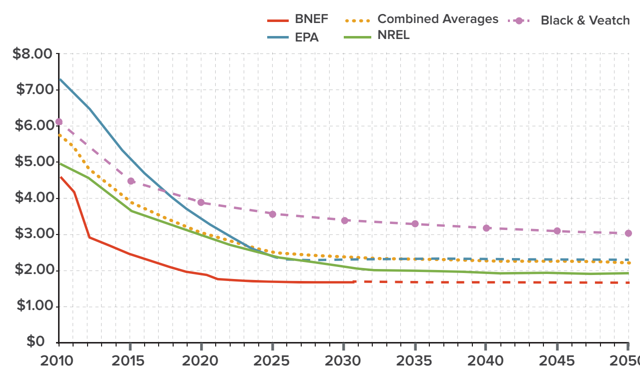
1. NREL Strategic Energy Analysis Center[31]
2. Bloomberg New Energy Finance (BNEF) Q2 2013 PV Market Outlook[32]
3. Environmental Protection Agency (EPA) Renewable Energy Costs Database[33]
4. Black & Veatch (B&V) Cost and Performance Data for Power Generation Technologies[34]

FIGURE 17: COMMERCIAL INSTALLED PV COST FORECASTS WITH RMI PROJECTIONS
[Y-AXIS 2012$/$W_{dc}$ - INSTALLED]



(DASHED LINES REPRESENT EXTRAPOLATIONS)

FIGURE 18: RESIDENTIAL INSTALLED PV COST FORECASTS WITH RMI PROJECTIONS
[Y-AXIS 2012$/$W_{dc}$ - INSTALLED]



(DASHED LINES REPRESENT EXTRAPOLATIONS)

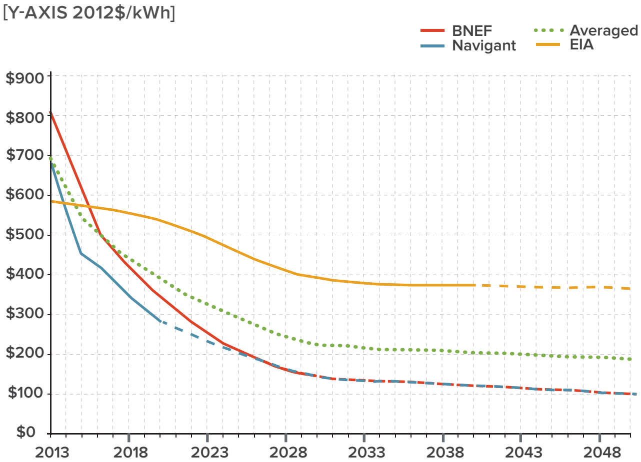
[xv] Additional information on solar PV and battery cost data can be found in Appendix A.
[xvi] These four sources proved to have the most reliable data available, both with regard to quantity and quality. Other datasets were considered but ultimately excluded from our analysis either because they had limited data points or were significantly divergent relative to current market costs (i.e., excessively high projections relative to present day installed costs).

Batteries

Our base case model uses a lithium-ion (Li-ion) battery to provide energy storage. We focus on Li-ion batteries because there is the most data on current and future pricing for this set of chemistries. Li-ion batteries are the clearly preferred chemistry for portable and vehicular applications. For stationary applications, such as what this analysis considers, there are many other chemistries under development. We don't focus on them because there is less data available about them—this doesn't alter our fundamental points and conclusions, and in fact disruptive new developments in battery technology could only accelerate the time frames for reaching grid parity with solar-plus-battery systems.

We based our battery price projections on data from the EIA,[35] Bloomberg New Energy Finance,[36] and Navigant Research.[37] All of these projections employ a Li-ion battery learning curve derived from historic and projected consumer electric vehicle (EV) production.[xvii] These projections were applied to stationary Li-ion batteries with some modification to account for the differences between battery packs for stationary and mobile applications.[38]

FIGURE 19: BATTERY PRICE PROJECTIONS
[Y-AXIS 2012$/kWh]

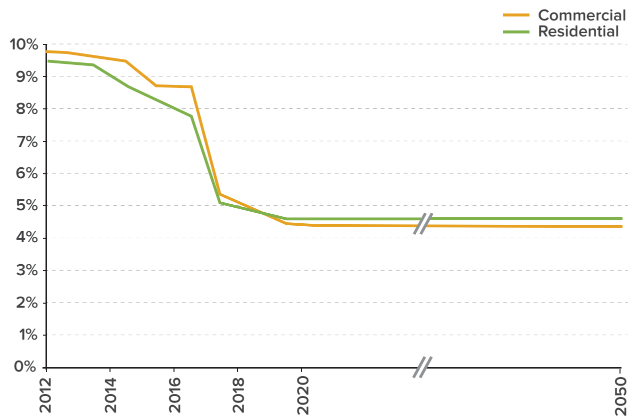


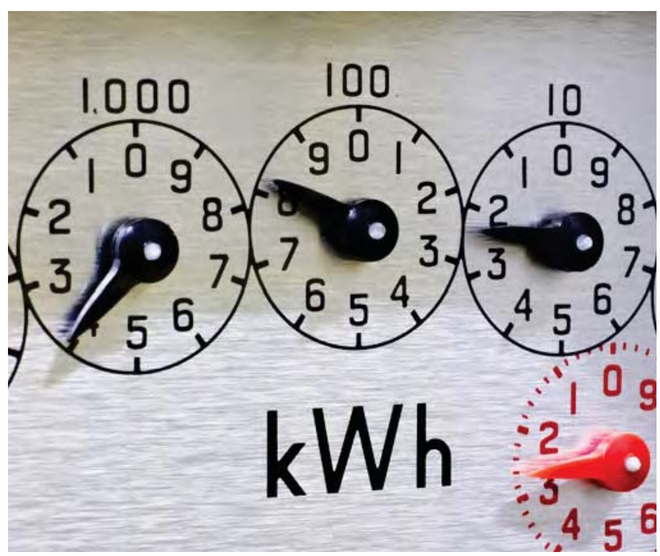
(DASHED LINES REPRESENT EXTRAPOLATIONS)

Cost of Capital

Costs of capital can have a substantial influence on customer-facing costs. Our base case model uses separate NREL-derived[39] capital costs for residential and commercial systems.[xviii] Importantly, solar PV systems (and, we expect, batteries in due course) are gaining access to cheaper sources of bulk capital and are expected to continue to enjoy that access.

FIGURE 20: COST OF CAPITAL COMPARISON
[Y-AXIS INTEREST RATES]





[xvii] The EIA Li-ion trend was significantly more conservative than similar, yet shorter term, Li-ion projections available from BNEF and Navigant. To the best of our knowledge from speaking with analysts, differing outlooks on the U.S. and global EV market largely drive these differences.
[xviii] The projected reductions in the residential cost of capital are largely predicated on the expansion of scalable homeowner financing products. The projected reductions in the commercial financing costs are based upon the expansion of several improved host-financing options to include green bonds and property assessed clean energy (PACE) programs.

BEYOND BASE CASE

Solar-Plus-Battery Technology and Demand-Side Improvement Assumptions

Our base case scenario framed the possibility for solar-plus-battery systems to reach grid parity under current trajectories—declining costs and increasing adoption rates—with no radical, disruptive improvements or other developments. We considered four scenarios in total, including three scenarios that would accelerate the timing of grid parity:

1. Base Case (BC)
2. Accelerated Technology Improvement (ATI)
3. Demand-Side Improvement (DSI)
4. Combined Improvement (CI)

BASE CASE	ACCELERATED TECHNOLOGY IMPROVEMENT	DEMAND-SIDE IMPROVEMENT	COMBINED IMPROVEMENT
The base case scenario is built upon generally accepted cost trajectories for all technologies involved. It examines the cost of entirely off-grid solar-plus-battery systems. This scenario uses the current industry projections for solar PV costs and battery costs shown in Figures 17, 18, and 19. These represent a conservative view of incremental progress with existing solar PV and battery technologies. Under the base case scenario, we assume there are no radical improvements in technology performance or costs.	The accelerated technology improvement scenario considers the impacts of sharply decreased total installed PV costs along with more aggressive battery price projections. ***Solar PV*** The U.S. Department of Energy's SunShot Initiative[40] has goals of $1.50/watt and $1.25/watt (in 2010-$) for residential and commercial installations, respectively, by 2020. These SunShot goals were included as the PV costs in our accelerated technology improvement scenario. ***Batteries*** We conducted a range of interviews with energy storage experts from major national laboratories, energy storage system integrators, and battery technology companies. Our interviews yielded a range of price projections that varied between $49 and $300 per kWh. To model the battery for the accelerated technology improvement scenario, we took the target battery price of $125/kWh, well within our interview price range, set by the U.S. Department of Energy EERE Vehicle Technologies Office to be consistent with our use of the SunShot PV price targets.	The demand-side improvement scenario considers the impact of full implementation of cost-effective energy efficiency and user-controlled load flexibility to shift the load profile, especially during an allowed period of capacity shortage. Bundled investments in DSI and off-grid technologies could be a cost-effective value proposition well before standalone systems without DSI are effective. ***Efficiency*** We used efficiency measures profiled by the Lawrence Berkeley National Laboratory in its 2008 report *U.S. Building-Sector Energy Efficiency Potential.* ***Load flexibility*** Demand management capabilities that enable consumers to shift their load profile in response to resource availability also reduce the necessary size of the system. In the residential systems only, we modeled load management as a 2% capacity shortage. This requires load management[xix] for approximately 170 hours spread over many days over the course of the year, typically in the winter months when the solar resource is poorest.	The combined improvement scenario applies the lower-cost technologies considered in the accelerated technology improvement scenario, coupled with the more efficient and flexible load profile modeled in the demand-side improvement scenario. This scenario explores the same bundled investment strategy as the previous scenario, but assumes that aggressive DOE cost targets are met.

Table 3: Solar-Plus-Battery Scenario Descriptions

[xix] A more detailed explanation can be found in Appendix B.

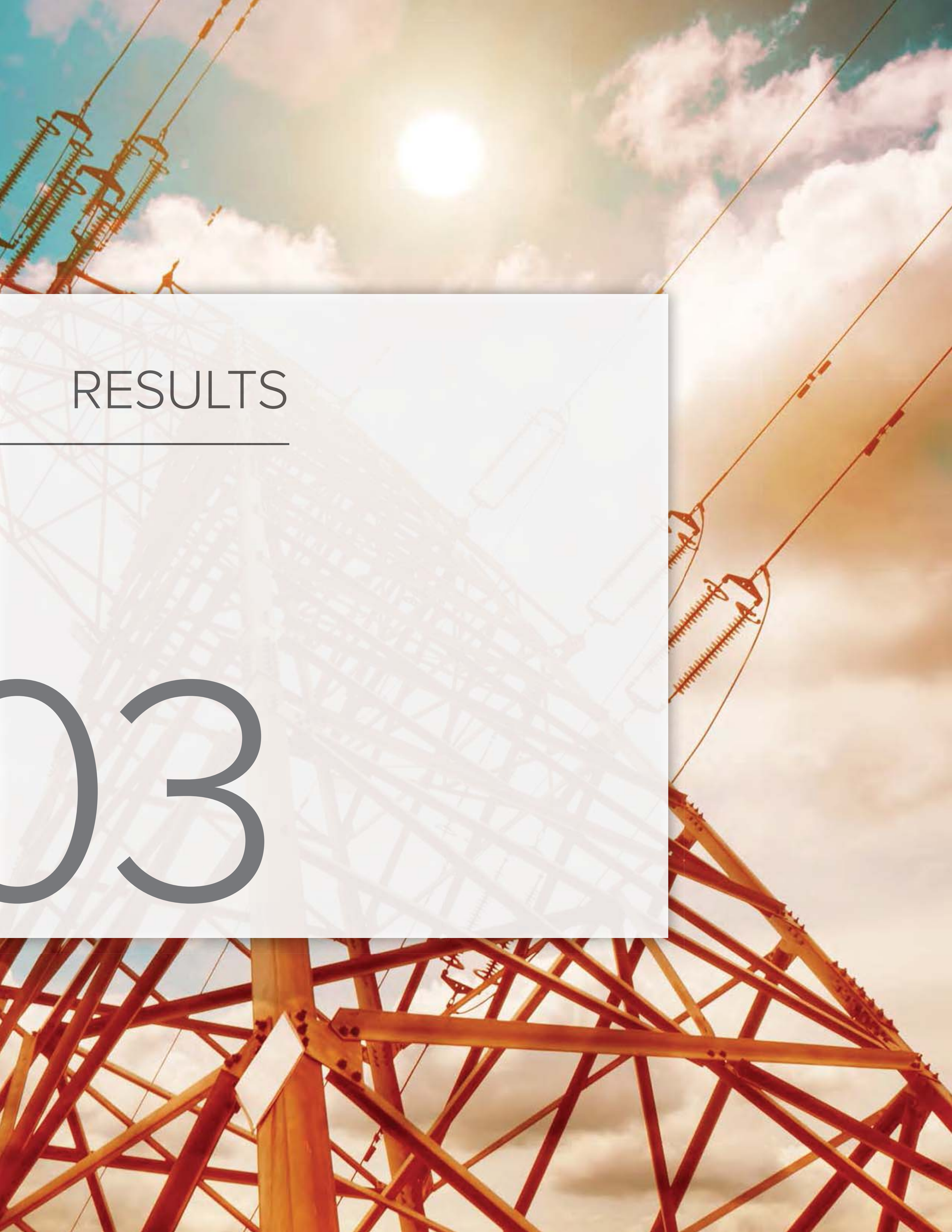
	COMMERCIAL			
	Base Case	Accelerated Technology Improvement	Demand-Side Improvement	Combined Improvement
PV Cost [$/W]	Average of selected forecasts	Straightline DOE 2020 Sunshot target of $1.25/W for all years	Average of selected forecasts	Straightline DOE 2020 Sunshot target of $1.25/W for all years
Li-ion Battery Cost [$/kWh]	Average of selected forecasts	Straightline DOE target of $125/kWh for all years	Average of selected Forecasts	Straightline DOE target of $125/kWh for all years
Efficiency Measures	No change in electric consumption over time	No change in electric consumption over time	34% reduction in electric use at a cost of $0.029/kWh	34% reduction in electric use at a cost of $0.029/kWh
Retail Electricity Price [$/kWh]*	Range: EIA projections (low) to 3% increase (high)			

	RESIDENTIAL			
	Base Case	Accelerated Technology Improvement	Demand-Side Improvement	Combined Improvement
PV Cost [$/W]	Average of selected forecasts	Straightline DOE 2020 Sunshot target of $1.50/W for all years	Average of selected forecasts	Straightline DOE 2020 Sunshot target of $1.50/W for all years
Li-ion Battery Cost [$/kWh]	Average of selected forecasts	Straightline DOE target of $125/kWh for all years	Average of selected forecasts	Straightline DOE target of $125/kWh for all years
Efficiency Measures	No change in electric consumption over time	No change in electric consumption over time	30% reduction in electric use at a cost of $0.029/kWh and 2% load flexibility	30% reduction in electric use at a cost of $0.029/kWh
Retail Electricity Price [$/kWh]*	Range: EIA projections (low) to 3% increase (high)			

Table 4: Solar-Plus-Battery Commercial and Residential Scenario Assumptions
*Grid parity calculated when LCOE intersected upper bound (3% increase) of projected retail electricity price

A Note on Pre-2020 Results

Our accelerated technology improvement scenario (and by extension, our combined improvement scenario) uses aggressive 2020 cost targets based on goals established by the U.S. Department of Energy. As these goals may be achieved in many different ways (e.g. new chemistries, supply-chain innovations, etc.) it was not possible to create a year-over-year representation of the improvement in technology before 2020 that would yield these costs. For this reason, the results for our accelerated technology improvement and combined improvement begin in 2020, and extend as possible cost targets beyond 2020. Due to the high innovation rates for both solar PV and batteries, it is conceivable that even these aggressive cost estimates underestimate the potential decline in component costs.



RESULTS

03

RESULTS

Our analysis for the base case found that solar-plus-battery grid parity is already here or imminent for certain customers in certain geographies, such as Hawaii. Grid parity will also arrive within the next 30 years (and in many cases much sooner) for a much wider set of customers in all but regions with the cheapest retail electricity prices. By 2050, we expect solar-plus-battery LCOEs to reach $0.33–$0.63 per kWh for residential systems and $0.16–$0.22 per kWh for commercial systems in our base case. These ranges were relatively narrow, so prevailing retail electricity prices in each geography proved the strongest influence on grid parity's timing, which we pinpointed as the intersection of solar-plus-battery costs with the upper bound of our utility price projections; slower utility retail price increases would push parity further into the future. It is important to note that these results are based on average load profiles; we might expect some minority of customers in each geography to see favorable economics much sooner.

COMMERCIAL APPLICATIONS

For commercial solar-plus-battery systems *with* a standby generator, grid parity is *already here* in Hawaii under all modeling scenarios. In other regions with high commercial retail electricity prices, such as the Northeast (Westchester County, NY, in our analysis), these systems will potentially become competitive with retail prices within the next ten years or so (as early as 2025). And in all regions, even those with the cheapest electricity—represented by Louisville, KY, and San Antonio, TX, in our analysis—parity will happen within the next 30 years under most modeling scenarios.

Commercial solar-plus-battery-only systems without a diesel genset will reach grid parity later—the 2030s for Westchester and Los Angeles, and even later for San Antonio and Louisville. However, in Hawaii these zero-emissions systems will reach grid parity by 2015. This shift in results underscores the large influence of battery costs. Adding a standby generator to a solar-plus-battery system dramatically reduces the capital required for the battery bank, bringing grid parity sooner.

COMMERCIAL PARITY TIMELINE

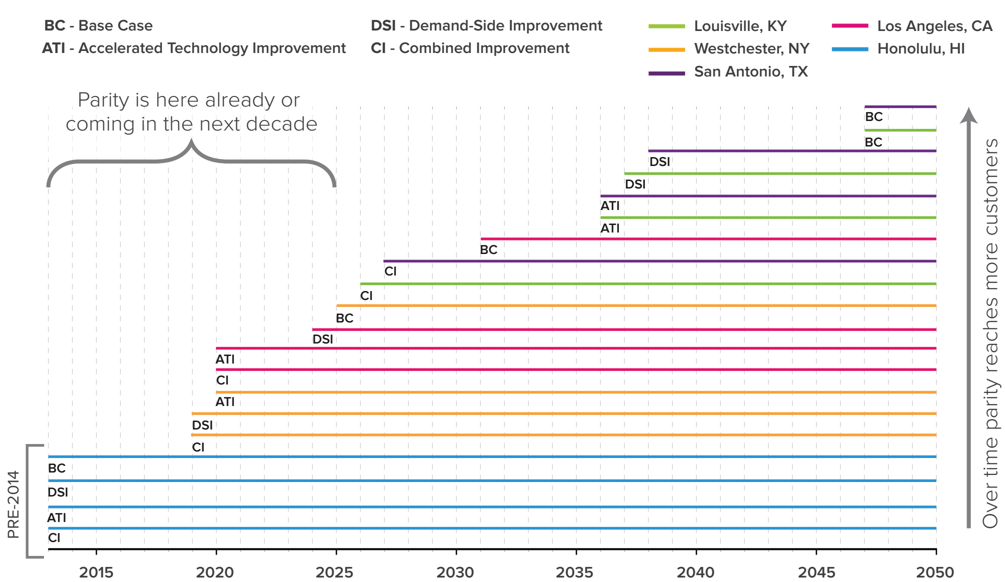
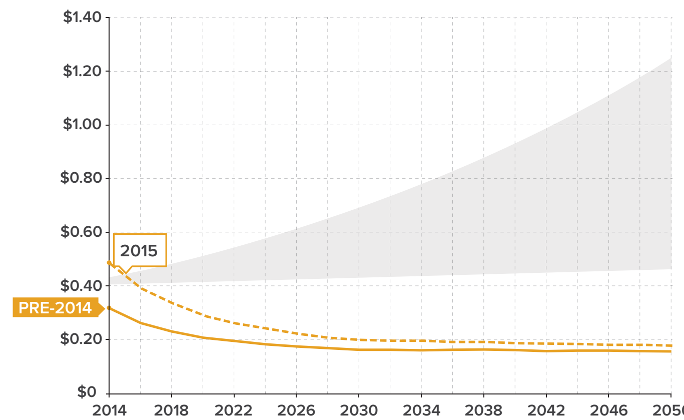


FIGURE 21: COMMERCIAL BASE CASE SCENARIOS

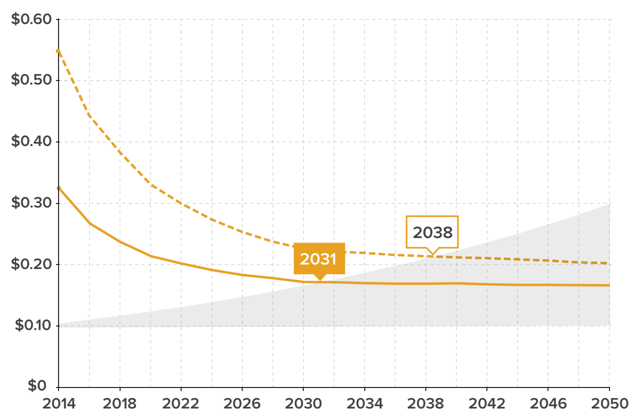
The following graphs show a wedge of utility electricity prices against the LCOE of solar-plus-battery systems for commercial customers with and without a diesel genset. All graphs in 2012$/kWh.

- Retail Electric Price Range
- Levelized Cost of Energy
- Levelized Cost of Energy (without Genset)

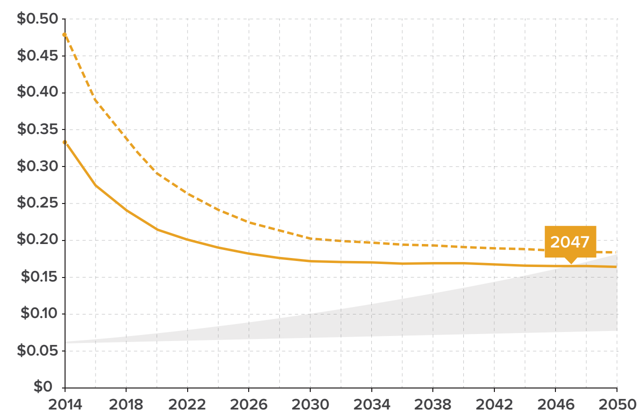
HONOLULU, HI



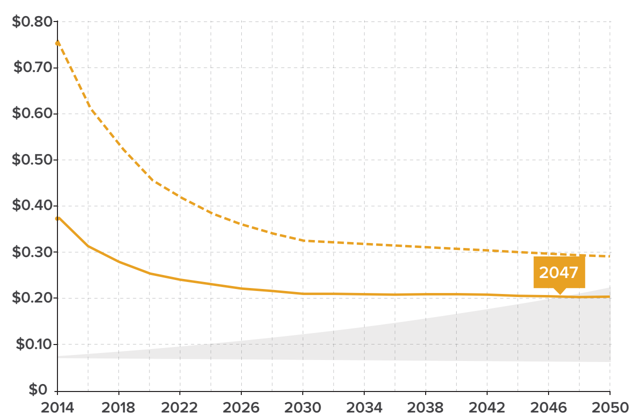
LOS ANGELES, CA



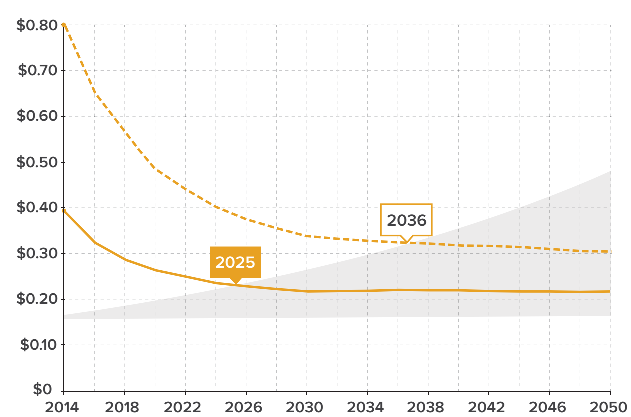
SAN ANTONIO, TX



LOUISVILLE, KY



WESTCHESTER, NY



RESIDENTIAL APPLICATIONS

Solar-plus-battery systems reach grid parity further into the future for residential applications, often by 5 to 10 years or more. Residential systems will reach grid parity as early as the early 2020s in Hawaii, late 2030s in Los Angeles, and late 2040s in Westchester in our base case. In Louisville and San Antonio, residential systems did not reach grid parity within the 2050 time horizon of our analysis.

However, just as a diesel generator accelerated grid parity for commercial systems, integrating demand-side improvements similarly accelerated the timeline for reaching grid parity. In Hawaii it could arrive in the next 1 to 2 years, in Los Angeles by the early 2020s, and in Westchester by the late 2020s.

Since we constrained the size of residential solar arrays, the LCOE trajectories for residential applications proved far more dependent on battery prices (See Figure 22). This makes demand-side improvements much more valuable for residential systems (See Figure 23), since efficiency lowers both peak and total demand, allowing downsized battery banks.

FIGURE 22: 2014 RESIDENTIAL BATTERY SIZES

[Y-AXIS kWh]

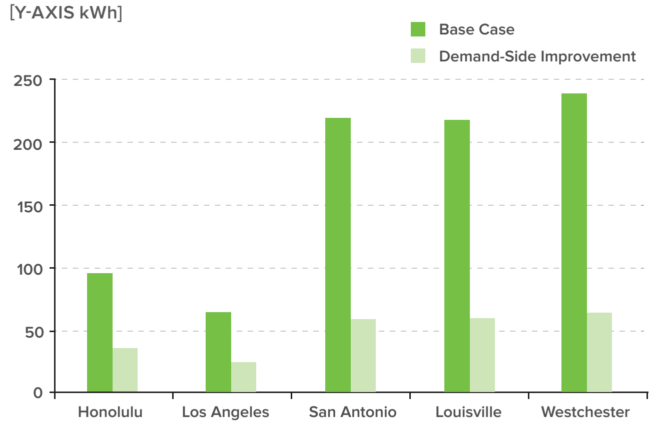
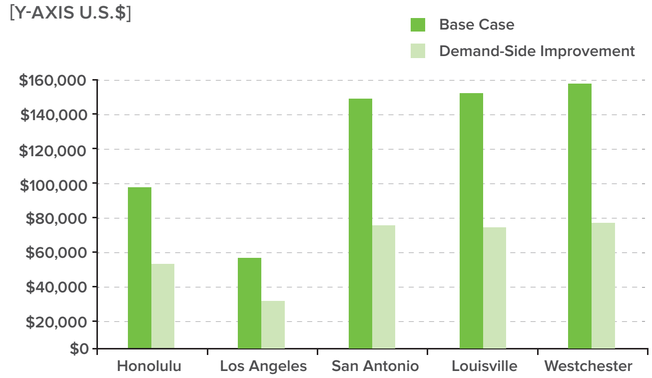


FIGURE 23: 2014 RESIDENTIAL CAPITAL COSTS

[Y-AXIS U.S.$]



RESIDENTIAL PARITY TIMELINE

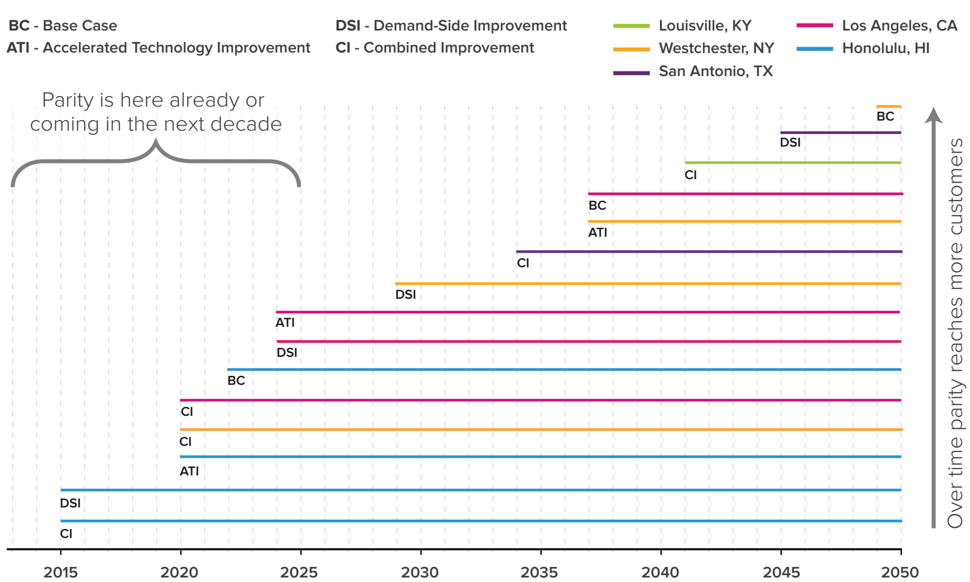


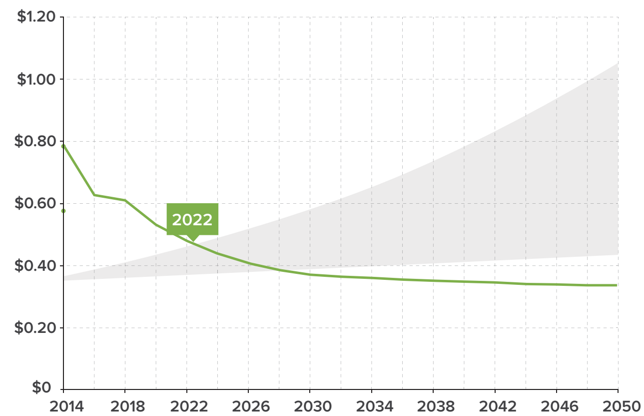
FIGURE 24: RESIDENTIAL BASE CASE SCENARIOS

The following graphs show a wedge of utility electricity prices against the LCOE of solar-plus-battery systems for residential customers. All graphs in 2012$/kWh.

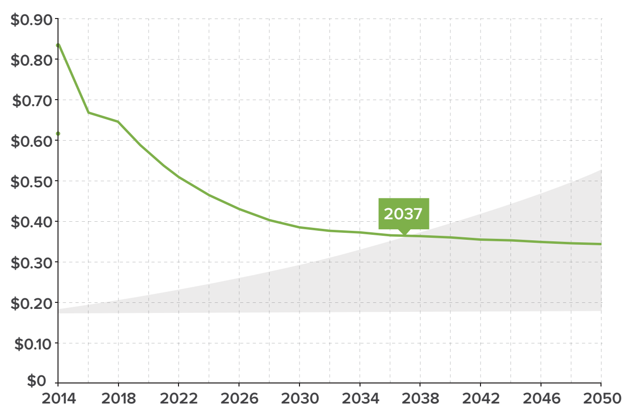
Retail Electric Price Range

Levelized Cost of Energy

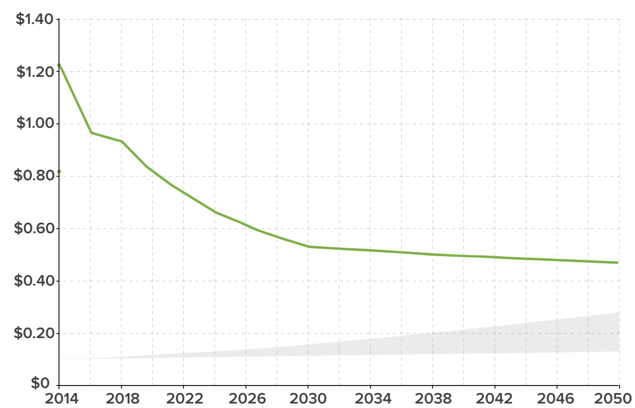
HONOLULU, HI



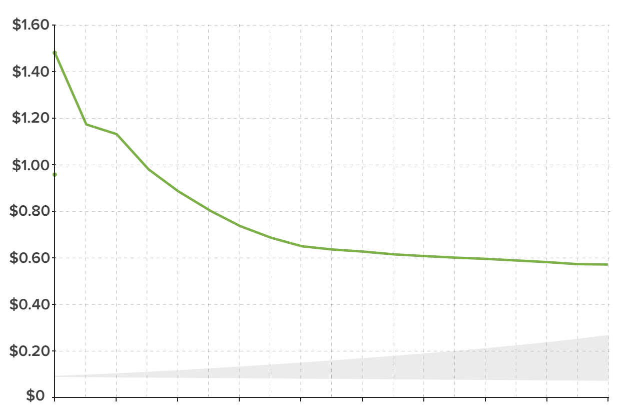
LOS ANGELES, CA



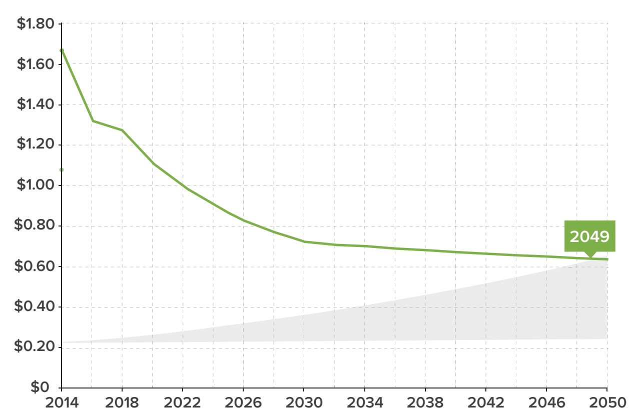
SAN ANTONIO, TX



LOUISVILLE, KY



WESTCHESTER, NY



ACCELERATED TECHNOLOGY IMPROVEMENTS AND DEMAND-SIDE IMPROVEMENTS—A FOCUS ON LOS ANGELES COUNTY

Our analysis found that accelerated technology improvements and demand-side improvements, both individually and in combination, accelerated the timeline for solar-plus-battery systems to reach grid parity. Examining the commercial profile in Los Angeles County, CA, provides a useful illustration of this trend across all five geographies. Remember that under the base case and as measured by LCOE, commercial systems in Los Angeles could reach grid parity as early as 2031.

Accelerated Technology Improvement

With accelerated technology improvements—based in part on reaching DOE cost targets for solar PV and battery technology by 2020—commercial systems in Los Angeles could reach grid parity as early as or even potentially before 2020, more than a decade ahead of the base case.

Demand-Side Improvement

We analyzed grid parity for integrated investments in demand-side improvements (efficiency and load flexibility) with solar-plus-battery systems using an adapted LCOE where we included the "negawatts served" by efficiency as part of the annual load served by the system. The LCOE of efficiency was held constant at its current cost of 2.7 cents per kWh.[41, xx]

Reducing a customer's load profile through demand-side improvements reduces the required system size and the number of kWh that system needs to generate. Relative to commercial retail prices in Los Angeles, demand-side improvements offer customers in the Los Angeles area favorable economics for solar-plus-battery systems as early as 2024, six years earlier than the base case.

FIGURE 25: GENERATION MIX 2024
LOS ANGELES - COMMERCIAL

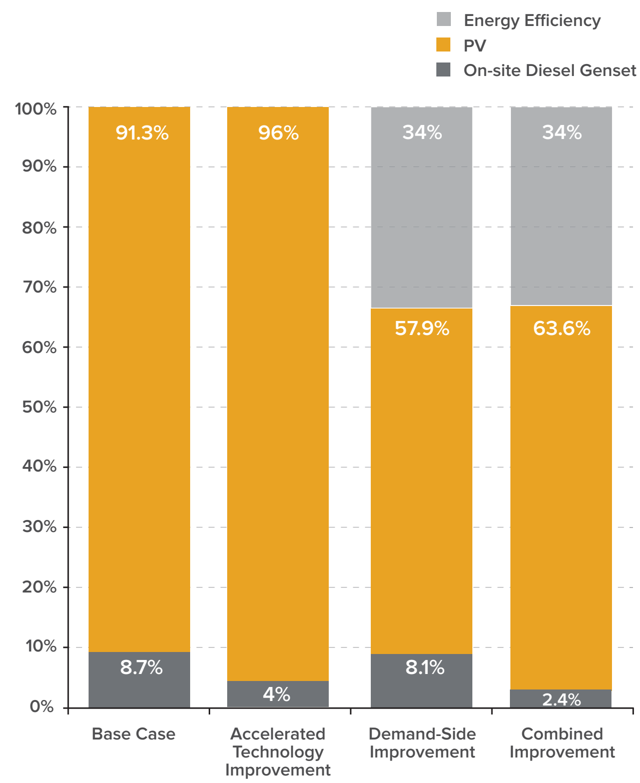
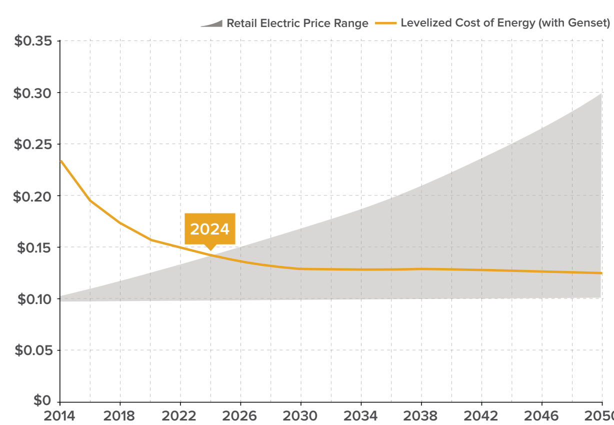


FIGURE 26: LOS ANGELES DEMAND-SIDE IMPROVEMENT



xx See Appendix B for a detailed description of our methodology.

Combined Improvement
Our analysis shows that combined improvements could reduce the levelized cost of energy for commercial systems by nearly 50% compared to our base case. Demand-side improvements reduce the size of the system, while technology improvements reduce the upfront cost of that smaller system, thus compounding the reductions in system costs. A commercial system with combined improvements eventually reaches an LCOE as low as $0.09/kWh. ***This LCOE makes solar-plus-battery systems competitive with today's retail electricity prices in Los Angeles.***

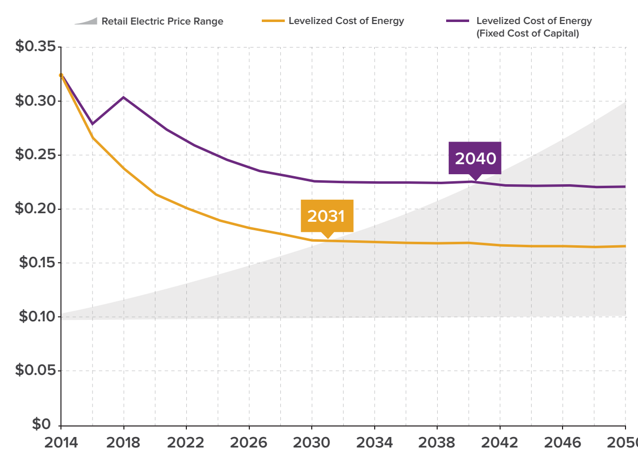
The Role of Financing: Cost of Capital Comparisons
Solar-plus-battery systems are long-term assets, which means they have an upfront capital cost, are likely to be financed at some interest rate, and would be paid off in monthly installments like a car or mortgage. Therefore, any cost-competitiveness comparison to the regular, monthly payments a customer would otherwise make to a utility will be dependent on reasonably low interest rates (5–9%) for solar-plus-battery financing.

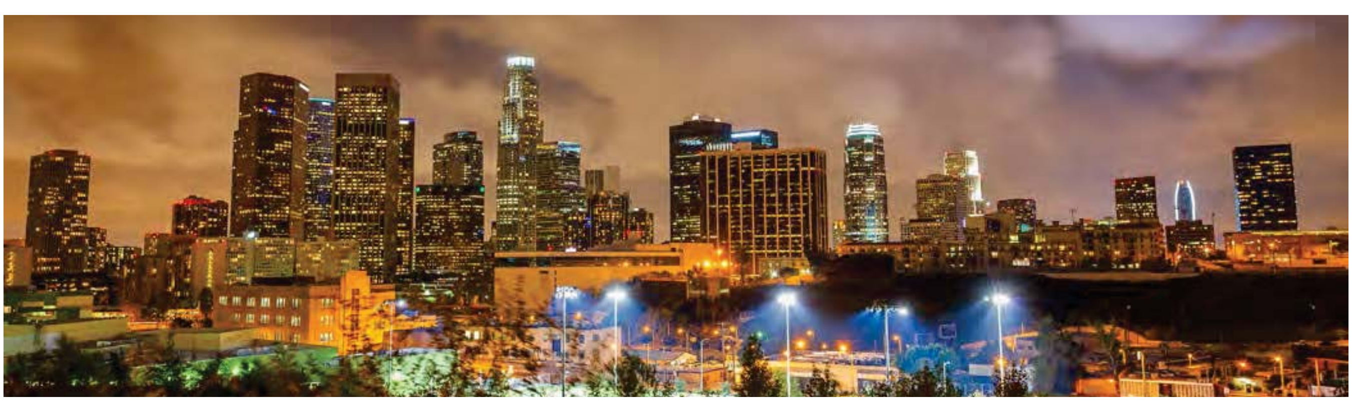
Today's market has created a variety of financing options for distributed generation (see box 'The Broader Finance Opportunities' page 33). While access to capital at low interest rates is essential to all of these options, we exclusively modeled host-owned systems (i.e., first-party owned).

We examined sensitivity to cost of capital by exploring two additional scenarios. The first assumed PV cost-of-capital improvements aligned with DOE's SunShot goals. The second assumed a fixed cost of capital over time, where solar-plus-battery systems are financed at similar rates to today's PV-only systems, even when the battery's percentage share of capital costs increases substantially.

The comparison of these two scenarios illustrate that a higher cost of capital (i.e., no improvements relative to today) for solar-plus-battery systems could postpone the date of grid parity by as much as ten years for commercial applications (See Figure 27).

FIGURE 27: LOS ANGELES COMMERCIAL BASE CASE FIXED COST OF CAPITAL[xxi]





[xxi] The dramatic uptick in LCOE for fixed cost of capital is due to the drop in the Investment Tax Credit from 30% to 10% in 2017. In the improving cost of capital alternative case, low-cost capital sources are engaged to continue the downward trend.

THE BROADER FINANCE OPPORTUNITIES

Third-party financing accounted for the majority of residential and commercial systems in the U.S. in 2013. The cost of capital for these third-party financings in 2013 was close to the rate of return that regulated utilities are allowed to receive on their investments (a proxy for the interest rate a utility would pass on to a customer), which are often about 10.5% nominal (about 8.0% real). Modeling a fixed cost of capital[xxii] is illustrative of two potential scenarios that could come to bear:

1. A scenario where third-party financing rates do not improve relative to current rates
2. A scenario where utilities invest in off-grid systems using the current rate of return they are permitted by regulatory statute.

Figure 27 (page 33) suggests that utilities would have to accept a lower rate of return (i.e., less profit) to compete with non-utility project developers should third-party financing rates improve at the expected rate. Improvements in lending rates require that solar-plus-battery systems prove to be robust systems in the long term and provide enduring value to the ultimate customer.

For PV, if not yet for batteries, the progress toward lower cost of capital appears to be occurring, as 2013 was a landmark year for the emergence of lower-interest financing vehicles. The first publicly known asset-backed securitization (ABS) of $54 million of SolarCity residential and commercial assets was achieved at 4.8% nominal yield. Also, a $431 million initial public offering was successfully achieved by NRG Yield, a steady yield- and dividend-oriented equity holding made up of a basket of power assets, including distributed solar systems with implied dividends of 7% by 2015.[42] These various and emerging finance vehicles allow renewables investments to tap a much wider investor pool; while a regulated utility would have trouble investing below its regulated rate, many public investors would be thrilled with a long-term, relatively stable return of 4.5–7%. Broader access to these public capital pools will be critical to hit DOE cost of capital targets.

[xxii] The regulated return utilities can receive varies by state and by rate case. The percentages listed reflect typical historic returns allowed to utilities, but should be taken as approximations. Our analysis used a trajectory that was developed from a composite of capital costs reported via industry surveys in 2012, and are not a perfect reflection of current market rates. Our trajectory suggests that capital costs will drop below 8% by 2016 for residential systems and 2017 for commercial systems.

BEYOND LOS ANGELES—A LOOK AT REGIONAL UTILITY DECILES

Though the Los Angeles commercial scenarios provide an insightful set of examples, looking more broadly at U.S. regions according to utility retail electricity sales deciles is revelatory as well.

Commercial Applications

We used 2012 utility sales EIA data to identify the distribution between the most expensive and least expensive MWh sold by utilities in the Southwest and the Mid-Atlantic, the two most populated regions considered in our study. Our Southwest and Mid-Atlantic sample set covered more than 390 TWh and 180 TWh of annual sales, and 25 million and 17 million customer accounts (meters), respectively. Our five study locations were generally in higher-priced regional deciles,[xxiii] as they are in urban locations within high load pockets where the highest regional prices prevail.

Looking ten years out to 2024, we found that solar-plus-battery systems in our base case will become cheaper than grid-sourced electricity from utilities for the most expensive one-fifth of load served. These two deciles represent nearly 800,000 commercial customers in the Southwest and over 450,000 customers in the Mid-Atlantic. With accelerated technology improvements, more than half of all commercial customers in these regions could “beat” retail utility electricity with solar-plus-battery systems. Between the two geographies, this represents over 3 million commercial customers and over $22 billion in annual utility revenues.

One of the major economic advantages of commercial systems over residential systems, other than slightly improved economies of scale via reduction of soft costs for solar PV and unrestricted solar array size, is the assumption of on-site, low-level-use diesel generation. The call-out box “The Honolulu Commercial Case” (page 36) provides more information on diesel generator use.

FIGURE 28: U.S. SOUTHWEST 2024 SOLAR-PLUS-BATTERY COMMERCIAL SCENARIOS VS. ESTIMATED UTILITY DECILES
[Y-AXIS - 2012$/kWh]

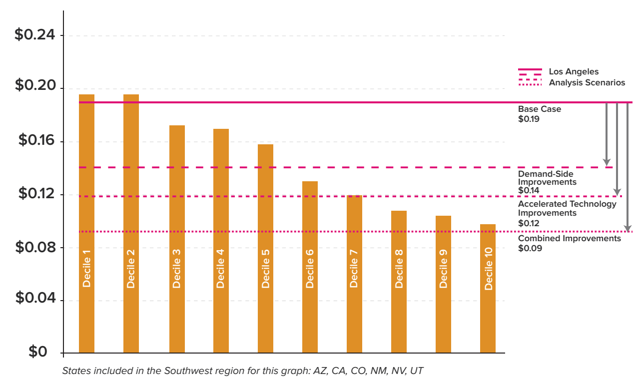
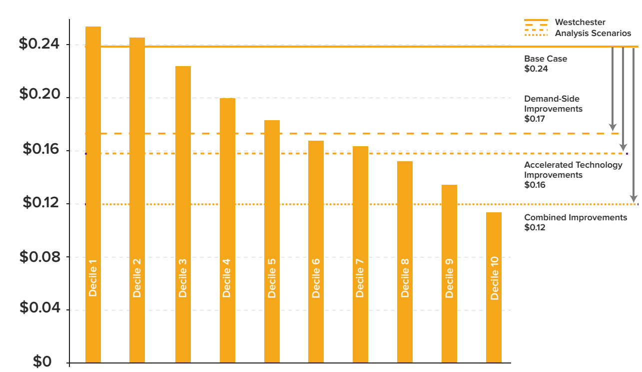


FIGURE 29: U.S. MID-ATLANTIC 2024 SOLAR-PLUS-BATTERY COMMERCIAL SCENARIOS VS. ESTIMATED UTILITY DECILES
[Y-AXIS - 2012$/kWh]



xxiii Deciles determined by MWh sold. Average prices of utilities were used, not specific tariffs. Average prices represent the revenue per energy unit sold, and is more difficult for a utility to alter than any specific customer tariff.

Residential Applications

For residential applications the improvements are less dramatic, but still significant. Given that space constraints and the lack of a diesel standby generator make the costs for residential systems heavily dependent on battery prices, parity for most mainland residential systems will not occur before 2024 without technology or demand-side improvements. However, accelerated technology improvements coupled with demand-side improvements stand to make solar-plus-battery systems competitive with retail electricity in those regions of the U.S. with the highest retail prices. Combined improvements will put hybrid systems clearly in the black for residential customers with higher rates, and will also create competitive opportunities in locations with more moderate retail prices.

In the Southwest, as many as 20 million residential customers could find economic advantage by 2024 with solar-plus-battery systems under our combined improvement scenario. In the Mid-Atlantic, roughly 8 million customers will find favorable economics for solar-plus-battery hybrid systems by 2024 given the same combined improvements. Between the two geographies this represents over $34 billion in annual utility revenues.

FIGURE 30: U.S. SOUTHWEST 2024 SOLAR-PLUS-BATTERY RESIDENTIAL SCENARIOS VS. ESTIMATED UTILITY DECILES
[Y-AXIS - 2012$/kWh]

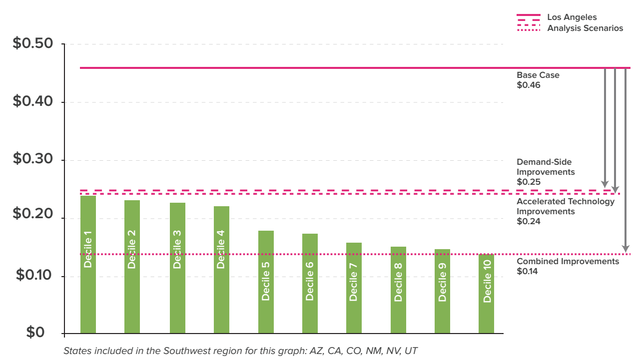
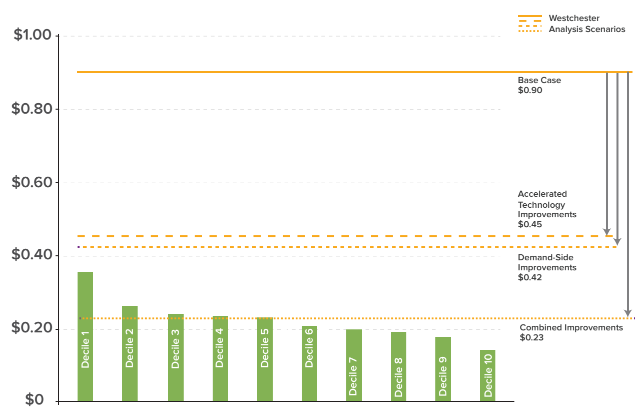


FIGURE 31: U.S. MID-ATLANTIC 2024 SOLAR-PLUS-BATTERY RESIDENTIAL SCENARIOS VS. ESTIMATED UTILITY DECILES
[Y-AXIS - 2012$/kWh]



THE HONOLULU COMMERCIAL CASE

The Honolulu commercial base case presents a startling result—it is already cost effective for a commercial customer to go off-grid with a solar-plus-battery with a standby diesel generator system. Even more startling, it will be cost effective for commercial customers to go off-grid with a zero-emissions solar-plus-batteries-only system next year.

So why haven't businesses done this? Well, some have, though not many. That's because multiple real challenges exist to scalable off-grid solutions. Most importantly, the standard business offering inclusive of installation and financing has not yet evolved to meet the opportunity. Further optimization of battery controls best suited to off-grid applications and communication systems signaling issues requiring O&M are all part of this need. For Hawaii, the economics have arrived faster than the required turnkey, scalable business models that can make it widespread.

Our commercial analysis included low-level use of on-site diesel generators, which reduces the required size of the PV array and battery bank. In the 2013 simulation, the diesel generator runs about 1,000 hours (~11% of the year). As the cost of PV and batteries decreases over time, the optimal system reduces generator run time to about 250 hours (~3% of the year). While this run time is substantially lower, it still presents real issues related to environmental permitting and noise considerations.[xxv] In both instances (2013 and later years), fuel costs comprise 15–20% of total lifetime costs.

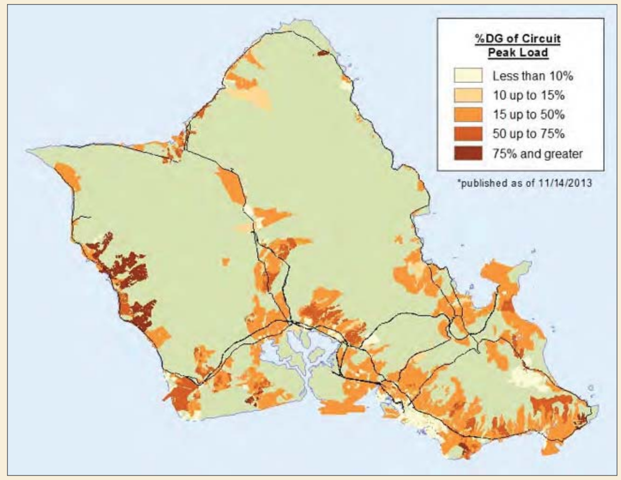


Figure 32: Oahu circuits with installed PV up to and greater than 100% of peak load (from 9 a.m. to 5 p.m.).[43, xxiv] Map courtesy of Hawaiian Electric. Used with permission.

Removing the generator from the system does increase the cost for a commercial system that provides grid-equivalent reliability, but not as substantially as one might think, largely due to the solar resource in this particular location. Due to the high retail electricity prices in Hawaii, a solar-plus-battery-only system (i.e., without diesel generator) becomes competitive with retail electricity by 2015.

Most Hawaii businesses are likely just beginning to become aware of the drop in technology costs and the financial vehicles that can be used to support their purchase of combined solar-plus-battery systems.

[xxiv] From RMI discussions with solar developers and the Hawaii PUC in Nov. 2013, interconnection evaluation wait times for proposed new systems on circuits at 100% or greater than minimum daytime load were extraordinary (a year or more).
[xxv] For a more detailed discussion of diesel standby generator permitting, emissions, and run time, see Appendix F.

CONCLUSION

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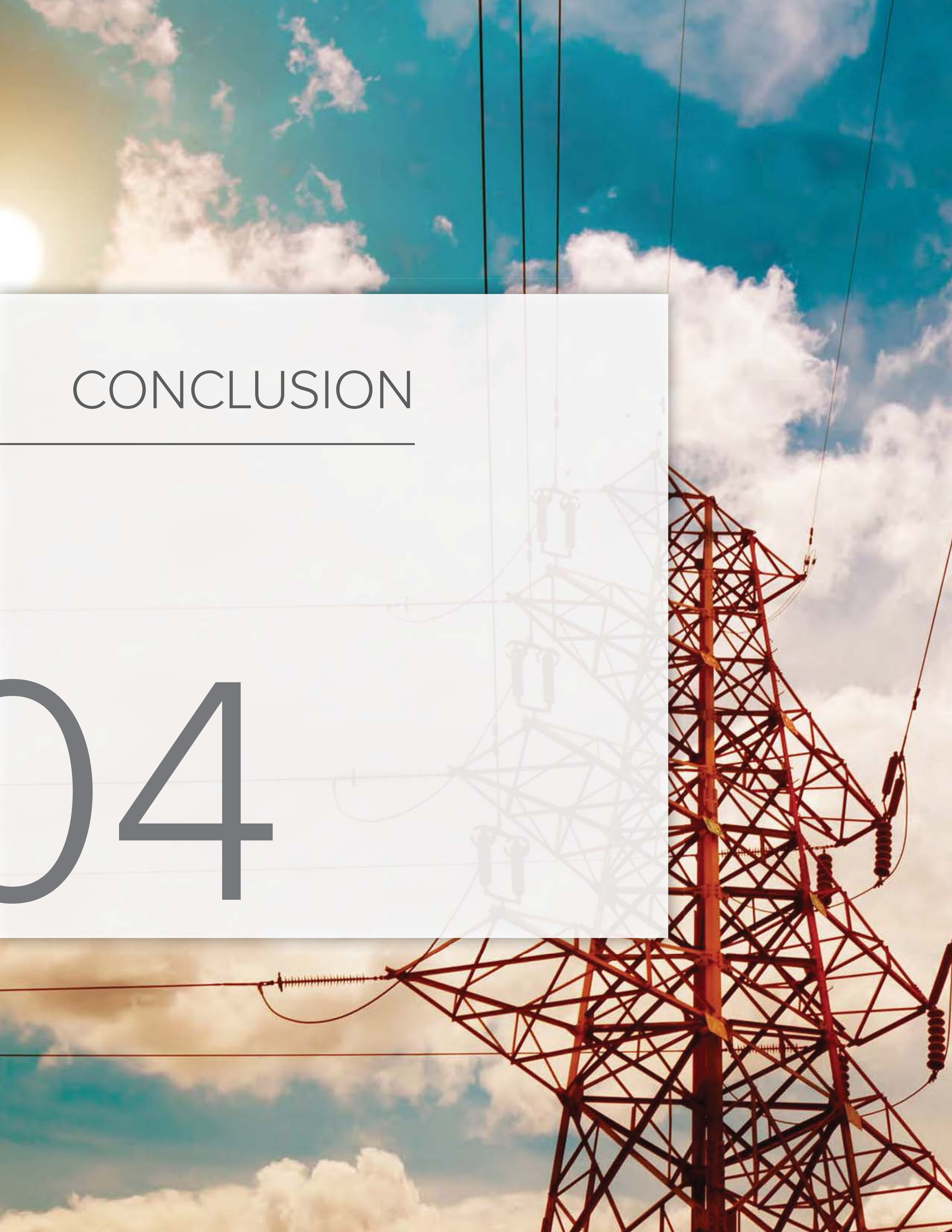
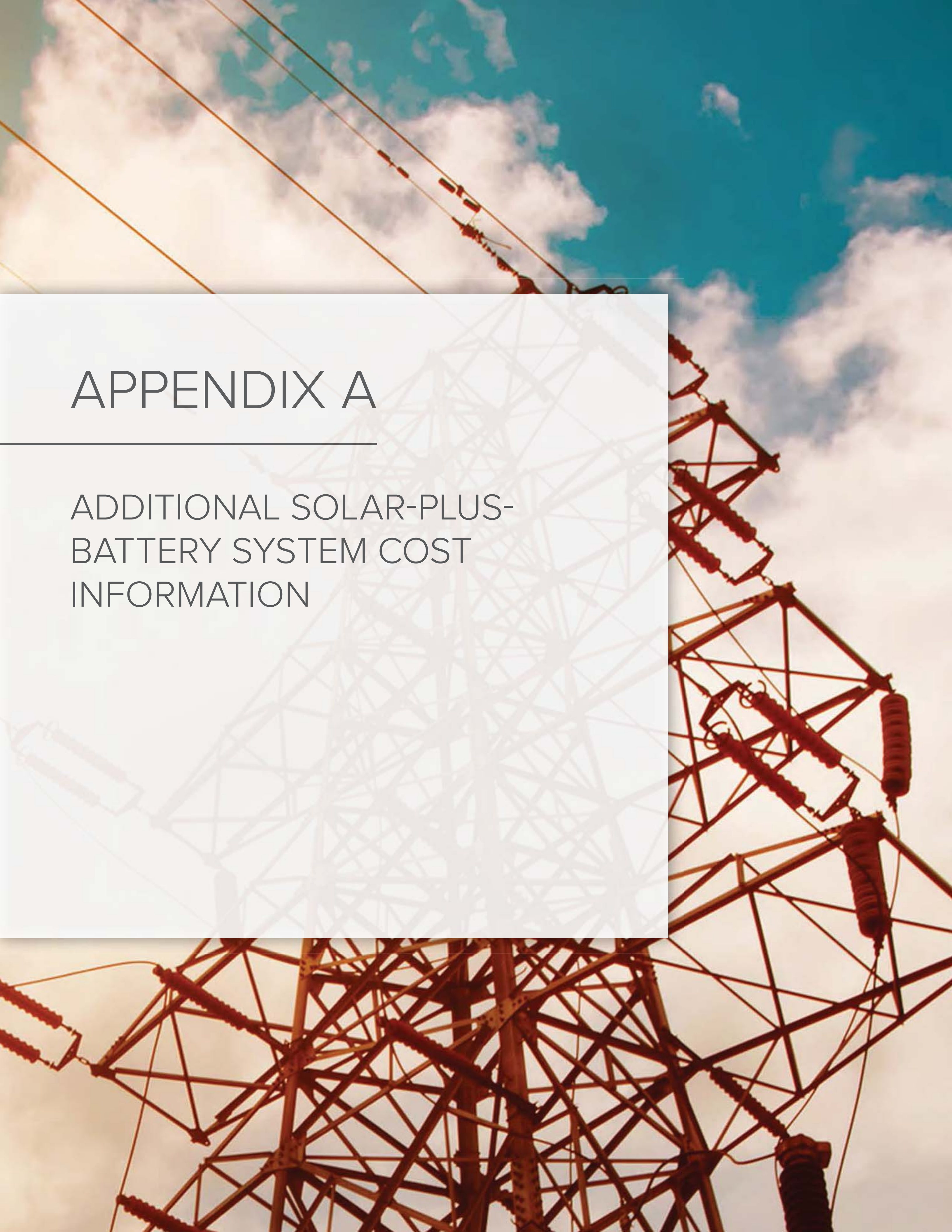


CONCLUSION

Rising retail electricity prices (driven in part by rising utility costs), increasing energy efficiency, falling costs for distributed energy technologies such as solar-plus-battery systems, and increasing adoption of distributed energy options are fundamentally shifting the landscape of the electricity system. Our analysis shows that solar-plus-battery systems will reach grid parity—for growing numbers of customers in certain geographies, especially those with high retail electricity prices—well within the 30-year period by which utilities capitalize major power assets. Millions of customers, commercial earlier than residential, representing billions of dollars in utility revenues will find themselves in a position to cost effectively defect from the grid if they so choose.

The so-called utility death spiral is proving not just a hypothetical threat, but a real, near, and present one. The coming grid parity of solar-plus-battery systems in the foreseeable future, among other factors, signals the eventual demise of traditional utility business models. Furthermore, early adopters and kWh sales decay will make utilities feel the pinch even before the rapidly approaching day of grid parity is here, while more aggressive technology improvements and investments in demand-side improvements beyond our base case would accelerate grid parity. Though utilities could and should see this as a threat, especially if they cling to increasingly challenged legacy business models, they can also see solar-plus-battery systems as an opportunity to add value to the grid and their business. When solar-plus-battery systems are integrated into a network, new opportunities open up that generate even greater value for customers and the network (e.g., potentially better customer-side economics, additional sizing options, ability of distributed systems to share excess generation or storage). The United States' electric grid is in the midst of transformation, but that shift need not be an either/or between central and distributed generation. Both forms of generation, connected by an evolving grid, have a role to play.

Having conducted an analysis of when and where grid parity will happen in this report, the important next question is how utilities, regulators, technology providers, and customers might work together to reshape the market—either within existing regulatory frameworks or under an evolved regulatory landscape—to tap into and maximize new sources of value offered by these disruptive opportunities to build the best electricity system of the future that delivers value and affordability to customers and society. The implications of these disruptive opportunities on business model design are the subject of ongoing work by the authors and their institutions, covered in a forthcoming report to follow soon.



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.

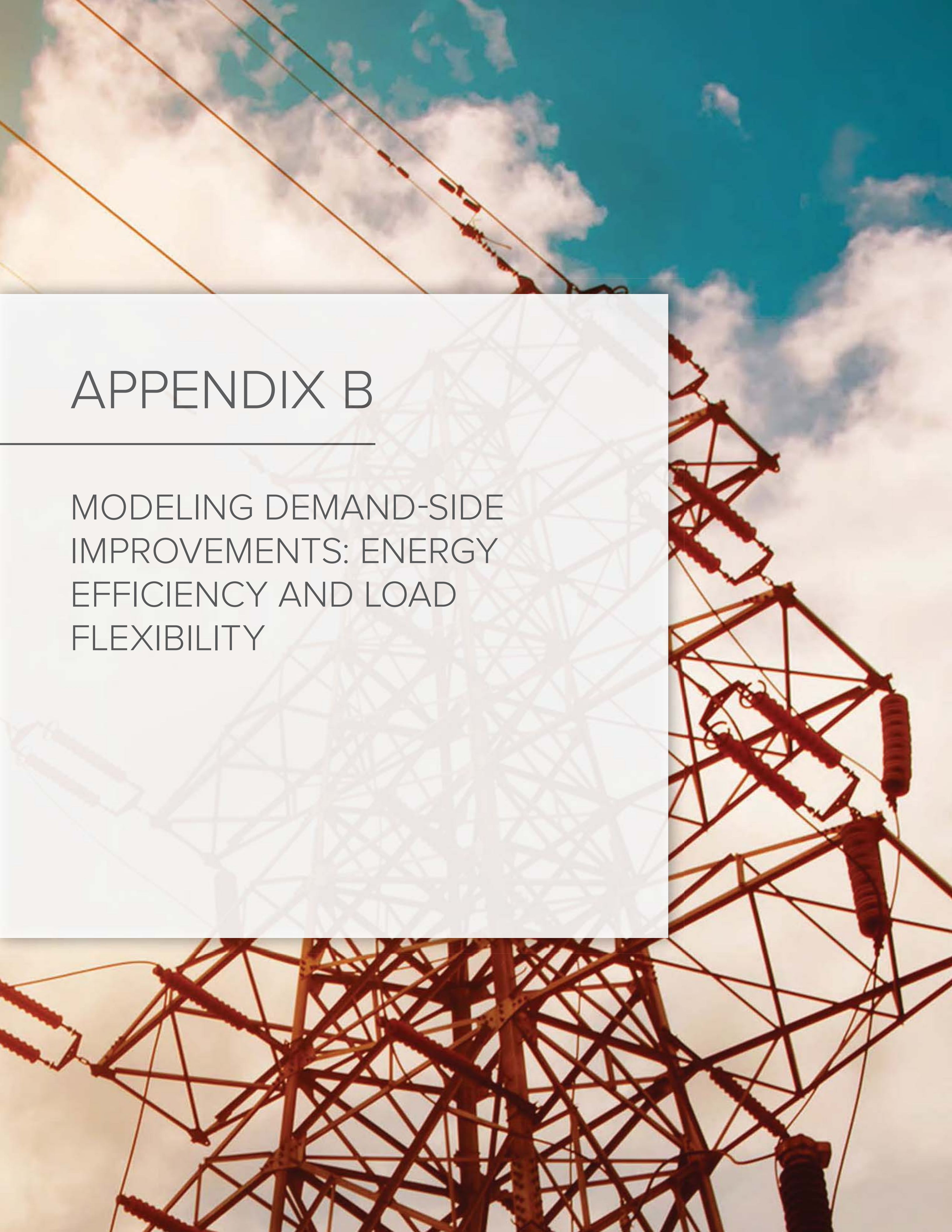
With this data, we calculated the proportion of total installed PV costs that came from the inverter alone. The average, 8%, was used to separate the installed curve into separate “PV without inverter” and “inverter” values.

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.[xxvi] 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 (see Figure 19). 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.

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



APPENDIX B

MODELING DEMAND-SIDE IMPROVEMENTS: ENERGY EFFICIENCY AND LOAD FLEXIBILITY

APPENDIX B

MODELING DEMAND-SIDE IMPROVEMENTS: ENERGY EFFICIENCY AND LOAD FLEXIBILITY

Energy efficiency

Energy efficiency reduces overall energy consumption, such as through improved lighting (e.g., switching from incandescent bulbs to compact fluorescent bulbs or light emitting diodes), Energy-Star-rated appliances, and improved insulation to reduce heating and cooling demand for buildings.

Our team based the set of efficiency interventions and the cost of efficiency on a study by Lawrence Berkeley National Laboratory.[44] This study drew upon several prior efficiency-potential studies and compiled technical data to estimate savings percentages and costs of conserved energy. This report modeled that conserving energy costs $0.027/kWh[xxvii] in 2007 U.S. dollars, with the total energy saved with energy efficiency measures 30% (residential scenarios) and 34% (commercial scenarios). These costs were converted to 2012 U.S. dollars[45] and the energy reduction applied to the load profiles.

Load flexibility

In the residential systems, our demand-side improvement scenario allowed for about 170–200 hours of managed load flexibility during the year, representing a 2% capacity shortage from the full load. Our electrical demand profile was, otherwise, a rigid electrical load profile requiring electricity on demand. Allowing a capacity shortage means that the owners of the system reduce or shift their energy use, either manually or automatically, predominantly during winter months.

Residential load management requires that residents either reduce or shift their loads in response to energy shortages. Much like an EV owner monitors the state of the battery charge on their vehicle and adapts their driving behavior accordingly, a homeowner with a solar-plus-battery system will have a similar ability to respond to the state of charge on their system. In winter months, when a period of cloudy weather is expected, homeowners will be able to respond by shifting when they use electricity or reducing their total consumption. This may mean waiting to wash clothes, washing dishes by hand, using lower settings on a dryer, programming appliances to run during the day, or foregoing certain energy-intensive activities like running a vacuum until the system can handle that demand.

User-controlled load flexibility was not included in the commercial systems.

xxvii $0.027/kWh is a national average; some regions and programs will have lower or higher costs.

COMMERCIAL	WESTCHESTER	LOUISVILLE	SAN ANTONIO	LOS ANGELES	HONOLULU
Energy Saved (kWh)	196,292	205,683	228,024	199,378	245,744
Yearly Cost of Conserved Energy (2012$)	$5,717	$5,991	$6,642	$5,807	$7,158

Table A1 – Commercial demand-side improvement inputs

RESIDENTIAL	WESTCHESTER	LOUISVILLE	SAN ANTONIO	LOS ANGELES	HONOLULU
Energy Saved (kWh)	3,584	3,854	4,576	2,379	4,342
Yearly Cost of Conserved Energy (2012$)	$104	$112	$133	$69	$126

Table A2 – Residential demand-side improvement inputs

APPENDIX C

ADDITIONAL TECHNICAL PERFORMANCE ASSUMPTIONS

APPENDIX C
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 kWp	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 A3 – 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 A4 – Battery technical assumptions

Genset technical assumptions

Standby diesel gensets were included in commercial scenarios in recognition of the premium placed on reliable electricity for business and that many businesses already use a diesel genset for backup power.[xxviii]

PARAMETER	VALUE	DESCRIPTION	SOURCE
Fuel	Diesel	The fuel is combusted to make electricity; diesel was chosen for its wide availability	
Applicable scenarios	Commercial only	The genset was only allowed to operate in commercial scenarios	
Operational limit	25% of total energy	The generator was allowed to contribute only 25% of the total energy	Author-imposed constraint
Sizing basis	110% of annual peak load	Gensets are typically sized slightly higher than the peak load to improve reliability for meeting high loads while keeping the generator operating as close to peak efficiency as possible.	Professional experience
Permitting compliance	Tier IV compliant	Tier IV emissions standards are mandated by the U.S. Environmental Protection Agency to reduce harmful exhaust gases from diesel powered equipment. Tier IV compliance reduces particulate matter (PM) and nitrogen	Professional experience
Installed cost	$500/kW	The installed cost per unit of capacity	Professional experience validated with SME interviews
Operation & maintenance cost	$0.025/kW/hour of operation	The cost of operating and maintaining the generator per hour of operation	Professional experience validated with SME interviews
Peak fuel efficiency	~31%	The amount of input fuel energy converted into electricity at full genset output	Professional experience validated with SME interviews
Fuel efficiency @ 50% load	~25%	The amount of input fuel energy converted into electricity at 50% genset output	Professional experience validated with SME interviews

Table A5 – Genset technical assumptions

[xxviii] For more information on diesel generator permitting, emissions, and run time, also see Appendix F.

Inverter technical assumptions

An inverter converts electricity from alternating current (AC) to direct current (DC) and vice versa. Grid-tied inverter costs were derived from the PV costs listed in Appendix A. We calculated the cost breakdown based on the BNEF PV Market Outlook report.[46] 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.[xxix] 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.

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

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 A6 – Inverter technical assumptions

APPENDIX D

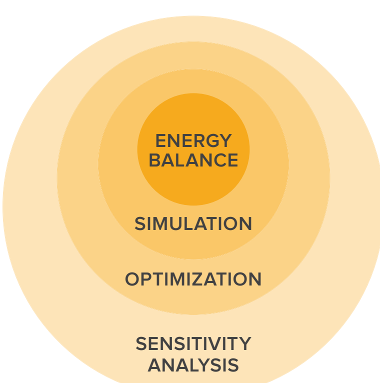
HOMER MODELING

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.

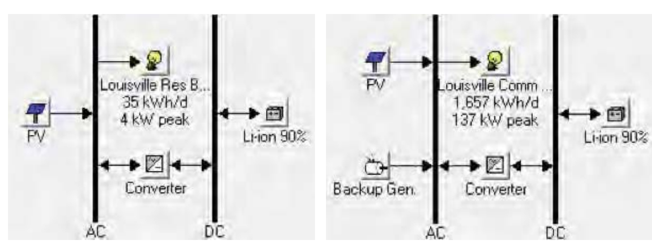
In addition to varying the capacity of the installed equipment, the user may also use HOMER's automated sensitivity analyses by varying the underlying assumptions for a location—for example, the cost of diesel fuel or the installed cost of equipment. Sensitivity analysis is different from optimization 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.[47] The HOMER model schematic for the Louisville residential and commercial models can be seen below.



APPENDIX E

FINANCIAL ASSUMPTIONS

APPENDIX E
FINANCIAL ASSUMPTIONS

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)		
	Residential	Commercial
2012	9.5%	9.7%
2013	9.4%	9.6%
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		4.5%
2020		
2021		
2022		
2023		
2024		
2025		
2026		
2027		
2028		
2029		
2030		
2031		
2032		
2033		
2034		
2035	4.6%	4.4%
2036		
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SunShot		

APPENDIX F

DIESEL STANDBY GENERATOR PERMITTING, EMISSIONS, AND RUN TIME

APPENDIX F

DIESEL STANDBY GENERATOR PERMITTING, EMISSIONS, AND RUN TIME

Permitting

In 2006, the EPA began regulating stationary non-road diesel engines (i.e., off-highway) to the same emissions standards as highway diesel engines (those used in trucks and other motor vehicles) and mobile non-road engines (those used in farm and construction equipment). The EPA had previously exempted all stationary diesel engines from emissions regulations, leaving the permitting of these engines largely to the discretion of local authorities having jurisdiction (AHJs).

The new EPA regulations require that stationary generators used for non-emergency applications (those operating >100 hours/year) meet Tier 4 or interim Tier 4 New Source Performance Standards (NSPS) by 2014. All non-emergency generators must be fully Tier 4 compliant by 2015. Tier 4 standards bring stationary generator emissions of NOx on par with those of natural-gas-powered equipment with the Best Available Control Technology (BACT).

While the new NSPS established the first uniform federal regulation for stationary diesel generators, local AHJs may still establish more restrictive standards based on local air quality conditions. Supplemental regulations generally require that BACT is employed to bring NO_x and particulate emissions below certain thresholds, and do not necessarily restrict the hours of runtime permitted for a generator unit.

Given the shift in permitting from a run-time restriction largely driven by local regulation to one in which run time is unrestricted but emissions are controlled, we chose to allow diesel generators to provide up to 25% of total load in commercial simulations. This upper limit was selected based on the guidance of IRS PLR 201308005, which requires that 75% of the energy stored by a battery in a hybrid system come from the solar PV for full eligibility of the ITC. A system that requires the generator to run 250–1,000 hours would likely require an investment in a modern, non-emergency generator by companies wishing to pursue solar-plus-battery solutions in the early years of grid parity.

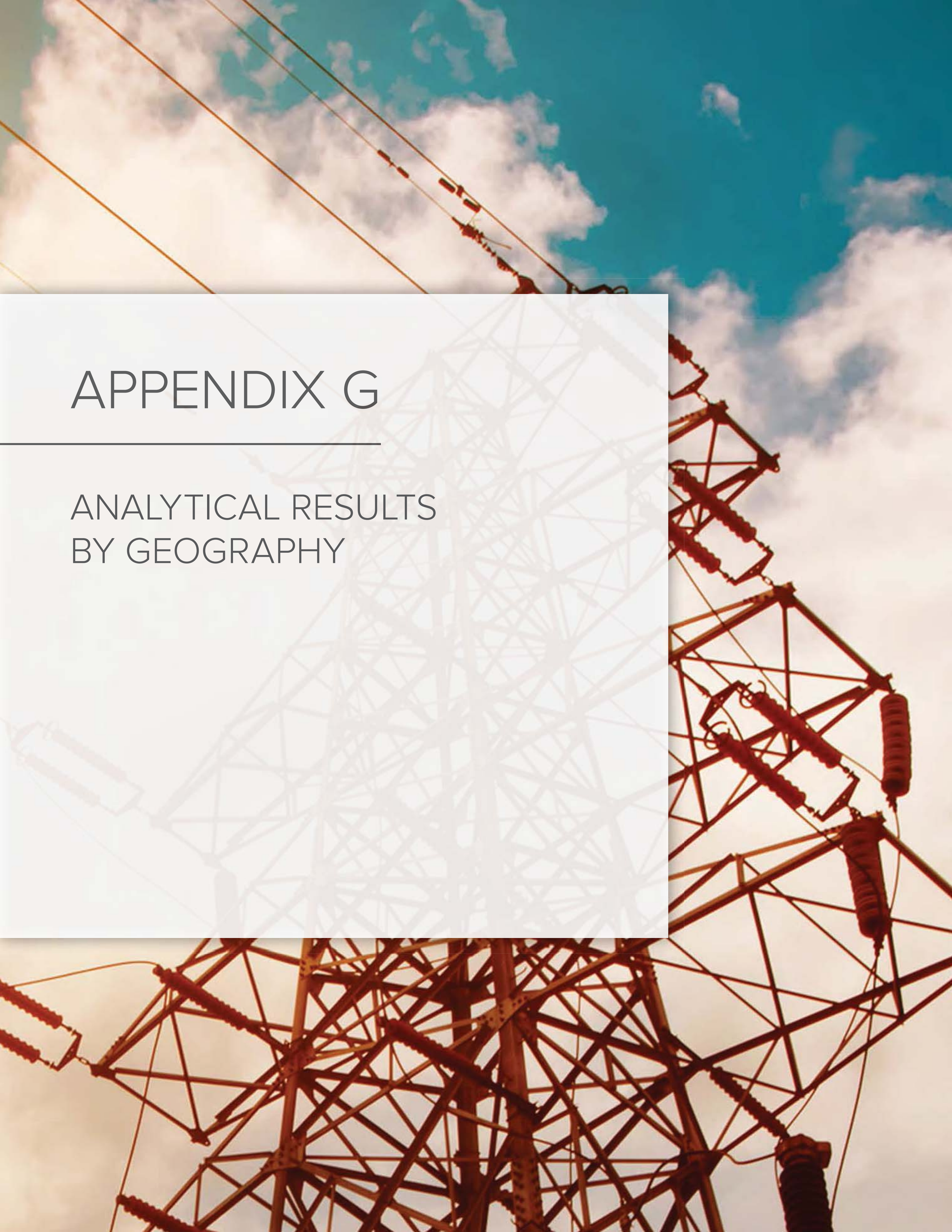
Emissions

While our commercial scenarios do rely on a diesel generator, it never supplies more than 25% of the electric demand, and in most cases far less than that. Despite the fact that diesel generators in our commercial scenarios are run more often than a typical backup generator, emissions are much lower than electricity purchased from the grid today.

In Westchester in 2014, for example, CO_2 emissions are 20% lower than the grid, in Los Angeles emissions are 43% lower, and remaining locations are all 73% lower. Since diesel generator use drops nearly in half (or more) by 2050, emissions experience similarly precipitous declines throughout the years.

APPENDIX G

ANALYTICAL RESULTS BY GEOGRAPHY



APPENDIX G
ANALYTICAL RESULTS BY GEOGRAPHY

COMMERCIAL TABLES - WESTCHESTER, NY

Base Case - Westchester Commercial (with Genset)

																					Emissions										
Year	PV	Diesel Genset	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Annual Cost	Operating Cost	COE	PV Production	Genset Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	CO2	CO	UHC	PM	SO2	NOx	Genset Fuel	Genset Hours	Genset Starts	Battery Autonomy	Battery Throughput
	kW	kW	Quantity	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	L/yr	hr/yr	starts/yr	hr	kWh/yr
2014	550	144	1,650	200	1,401,357	2,144,040	27,632	7,130	43,932	227,181	78,694	0.393	713,878	143,657	857,536	577,431	75%	0	0	194,553	126,851	313	35	24	255	2,794	48,171	1,064	102	20.03	322,170
2016	550	144	1,650	200	1,212,348	1,889,235	23,811	7,130	36,302	187,681	67,244	0.325	713,878	143,557	857,435	577,431	75%	0	0	194,417	126,784	313	35	24	255	2,792	48,146	1,064	101	20.03	322,299
2018	550	144	1,650	250	1,428,720	2,377,849	23,850	6,976	35,844	167,027	66,670	0.289	713,878	142,105	855,984	577,431	75%	0	0	193,001	124,525	307	34	23	250	2,743	47,288	1,021	96	20.03	322,139
2020	550	144	1,650	250	1,288,824	2,283,343	21,627	7,051	37,702	152,405	66,381	0.264	713,878	142,162	856,041	577,431	75%	0	0	193,121	125,199	309	34	23	251	2,758	47,544	1,042	96	20.03	321,906
2022	600	144	1,600	200	1,228,640	2,175,473	18,763	6,897	37,538	145,205	63,198	0.251	778,777	133,583	912,360	577,431	77%	0	0	249,542	119,096	294	33	22	239	2,623	45,226	1,027	96	19.42	320,944
2024	600	144	1,700	250	1,160,111	2,071,831	17,615	6,788	36,451	138,288	60,854	0.239	778,777	126,378	905,155	577,431	78%	0	0	241,729	111,744	276	31	21	224	2,461	42,434	941	81	20.64	322,629
2026	600	144	1,800	200	1,105,466	2,000,201	16,369	6,934	36,418	133,507	59,721	0.231	778,777	121,746	900,524	577,431	79%	0	0	236,960	108,240	267	30	20	217	2,384	41,104	926	74	21.85	323,257
2028	650	144	1,750	200	1,114,430	1,953,823	14,432	6,632	34,963	130,411	56,027	0.226	843,675	113,425	957,100	577,431	80%	0	0	293,714	101,063	249	28	19	203	2,226	38,378	870	73	21.24	322,719
2030	650	144	1,750	200	1,071,440	1,909,217	13,403	6,632	35,884	127,434	55,919	0.221	843,675	113,425	957,100	577,431	80%	0	0	293,714	101,063	249	28	19	203	2,226	38,378	870	73	21.24	322,719
2032	650	144	1,750	200	1,064,038	1,911,742	13,068	6,632	36,882	127,602	56,581	0.221	843,675	113,425	957,100	577,431	80%	0	0	293,714	101,063	249	28	19	203	2,226	38,378	870	73	21.24	322,719
2034	650	144	1,750	200	1,052,183	1,917,526	12,825	6,632	38,302	127,988	57,759	0.222	843,675	113,425	957,100	577,431	80%	0	0	293,714	101,063	249	28	19	203	2,226	38,378	870	73	21.24	322,719
2036	650	144	1,750	200	1,041,378	1,917,028	12,630	6,632	39,184	127,955	58,447	0.222	843,675	113,425	957,100	577,431	80%	0	0	293,714	101,063	249	28	19	203	2,226	38,378	870	73	21.24	322,719
2038	650	144	2,050	250	1,081,349	1,922,133	13,905	6,832	35,382	128,296	56,119	0.222	843,675	100,589	944,264	577,431	83%	0	0	279,391	89,246	220	24	17	179	1,966	33,891	759	57	24.88	328,553
2040	650	144	2,050	250	1,070,708	1,927,984	13,718	6,832	36,670	128,686	57,220	0.223	843,675	100,589	944,264	577,431	83%	0	0	279,391	89,246	220	24	17	179	1,966	33,891	759	57	24.88	328,553
2042	650	144	2,050	250	1,066,280	1,904,802	13,517	6,832	35,619	127,139	55,969	0.22	843,675	100,589	944,264	577,431	83%	0	0	279,391	89,246	220	24	17	179	1,966	33,891	759	57	24.88	328,553
2044	600	144	2,600	300	1,072,700	1,899,404	16,054	7,572	31,553	126,779	55,180	0.22	778,777	87,811	866,588	577,431	85%	0	0	198,265	77,800	192	21	14	156	1,714	29,544	659	43	31.56	339,766
2046	600	144	2,600	300	1,067,448	1,898,532	15,815	7,572	32,085	126,721	55,472	0.219	778,777	87,811	866,588	577,431	85%	0	0	198,265	77,800	192	21	14	156	1,714	29,544	659	43	31.56	339,766
2048	600	144	2,600	300	1,056,326	1,890,687	15,502	7,572	32,617	126,197	55,691	0.219	778,777	87,811	866,588	577,431	85%	0	0	198,265	77,800	192	21	14	156	1,714	29,544	659	43	31.56	339,766
2050	600	144	2,600	300	1,051,386	1,889,909	15,277	7,572	33,119	126,145	55,969	0.218	778,777	87,811	866,588	577,431	85%	0	0	198,265	77,800	192	21	14	156	1,714	29,544	659	43	31.56	339,766
Sunshot	600	144	2,600	300	748,508	1,367,318	10,303	7,572	23,429	91,264	41,303	0.158	778,777	87,811	866,588	577,431	85%	0	0	198,265	77,800	192	21	14	156	1,714	29,544	659	43	31.56	339,766

Base Case - Westchester Commercial (without Genset)

																			Emissions								
Year	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Annual Cost	Operating Cost	COE	PV Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	CO2	CO	UHC	PM	SO2	NOx	Battery Autonomy	Battery Throughput
	kW	Quantity	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	hr	kWh/yr
2014	1,300	5,200	500	3,522,972	4,375,041	79,885	10,400	0	463,577	90,285	0.803	1,687,349	1,687,349	577,017	100%	526	414	1,023,183	0	0	0	0	0	0	63.12	331,714
2016	1,300	5,200	500	3,003,580	3,790,150	67,740	10,400	0	376,522	78,140	0.653	1,687,349	1,687,349	577,017	100%	526	414	1,023,183	0	0	0	0	0	0	63.12	331,714
2018	1,300	5,200	500	3,542,116	4,637,121	66,516	10,400	0	325,725	76,916	0.564	1,687,349	1,687,349	577,017	100%	526	414	1,023,183	0	0	0	0	0	0	63.12	331,714
2020	1,300	5,200	500	3,169,112	4,213,621	59,317	10,400	0	281,245	69,717	0.487	1,687,349	1,687,349	577,017	100%	526	414	1,023,183	0	0	0	0	0	0	63.12	331,714
2022	1,300	5,200	500	2,880,080	3,828,097	52,877	10,400	0	255,513	63,277	0.443	1,687,349	1,687,349	577,017	100%	526	414	1,023,183	0	0	0	0	0	0	63.12	331,714
2024	1,300	5,200	500	2,635,516	3,496,222	47,049	10,400	0	233,361	57,449	0.404	1,687,349	1,687,349	577,017	100%	526	414	1,023,183	0	0	0	0	0	0	63.12	331,714
2026	1,300	5,200	500	2,464,124	3,250,525	42,090	10,400	0	216,962	52,490	0.376	1,687,349	1,687,349	577,017	100%	526	414	1,023,183	0	0	0	0	0	0	63.12	331,714
2028	1,300	5,200	500	2,352,792	3,081,225	38,220	10,400	0	205,661	48,620	0.356	1,687,349	1,687,349	577,017	100%	526	414	1,023,183	0	0	0	0	0	0	63.12	331,714
2030	1,300	5,200	500	2,244,936	2,927,952	35,189	10,400	0	195,431	45,589	0.339	1,687,349	1,687,349	577,017	100%	526	414	1,023,183	0	0	0	0	0	0	63.12	331,714
2032	1,300	5,200	500	2,222,940	2,891,031	34,193	10,400	0	192,967	44,593	0.334	1,687,349	1,687,349	577,017	100%	526	414	1,023,183	0	0	0	0	0	0	63.12	331,714
2034	1,300	5,200	500	2,194,028	2,851,316	33,472	10,400	0	190,316	43,872	0.33	1,687,349	1,687,349	577,017	100%	526	414	1,023,183	0	0	0	0	0	0	63.12	331,714
2036	1,300	5,200	500	2,168,236	2,816,855	32,893	10,400	0	188,016	43,293	0.326	1,687,349	1,687,349	577,017	100%	526	414	1,023,183	0	0	0	0	0	0	63.12	331,714
2038	1,300	5,200	500	2,157,056	2,798,053	32,384	10,400	0	186,761	42,784	0.324	1,687,349	1,687,349	577,017	100%	526	414	1,023,183	0	0	0	0	0	0	63.12	331,714
2040	1,300	5,200	500	2,133,552	2,767,439	31,910	10,400	0	184,717	42,310	0.32	1,687,349	1,687,349	577,017	100%	526	414	1,023,183	0	0	0	0	0	0	63.12	331,714
2042	1,300	5,200	500	2,122,320	2,748,563	31,400	10,400	0	183,457	41,800	0.318	1,687,349	1,687,349	577,017	100%	526	414	1,023,183	0	0	0	0	0	0	63.12	331,714
2044	1,300	5,200	500	2,098,400	2,717,256	30,907	10,400	0	181,368	41,307	0.314	1,687,349	1,687,349	577,017	100%	526	414	1,023,183	0	0	0	0	0	0	63.12	331,714
2046	1,250	5,350	600	2,063,018	2,699,372	31,774	10,700	0	180,174	42,474	0.312	1,622,451	1,622,451	577,022	100%	518	410	958,021	0	0	0	0	0	0	64.94	332,975
2048	1,250	5,350	600	2,039,979	2,666,752	31,135	10,700	0	177,997	41,835	0.308	1,622,451	1,622,451	577,022	100%	518	410	958,021	0	0	0	0	0	0	64.94	332,975
2050	1,250	5,350	600	2,029,814	2,649,667	30,673	10,700	0	176,856	41,373	0.306	1,622,451	1,622,451	577,022	100%	518	410	958,021	0	0	0	0	0	0	64.94	332,975
Sunshot	1,250	5,350	600	1,402,353	1,869,275	20,465	10,700	0	124,768	31,165	0.216	1,622,451	1,622,451	577,022	100%	518	410	958,021	0	0	0	0	0	0	64.94	332,975

Base Case - Westchester Fixed Cost of Capital (9.5%) with Genset

																					Emissions										
Year	PV	Diesel Genset	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Annual Cost	Operating Cost	COE	PV Production	Genset Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	CO2	CO	UHC	PM	SO2	NOx	Genset Fuel	Genset Hours	Genset Starts	Battery Autonomy	Battery Throughput
	kW	kW	Quantity	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	L/yr	hr/yr	starts/yr	hr	kWh/yr
2014	550	144	1,650	200	1,401,357	2,144,040	27,632	7,130	43,932	227,181	78,694	0.393	713,878	143,657	857,536	577,431	75%	0	0	194,553	126,851	313	35	24	255	2,794	48,171	1,064	102	20.03	322,170
2016	550	144	1,650	200	1,212,348	1,839,580	23,029	7,130	36,302	194,921	66,461	0.338	713,878	143,557	857,435	577,431	75%	0	0	194,417	126,784	313	35	24	255	2,792	48,146	1,064	101	20.03	322,299
2018	550	144	1,650	200	1,420,220	2,025,031	20,460	7,130	36,495	214,571	64,085	0.372	713,878	143,557	857,435	577,431	75%	0	0	194,417	126,784	313	35	24	255	2,792	48,146	1,064	101	20.03	322,299
2020	550	144	1,650	200	1,280,824	1,884,528	18,429	7,213	38,326	199,683	63,968	0.346	713,878	143,236	857,114	577,431	75%	0	0	194,116	127,271	314	35	24	256	2,803	48,331	1,087	100	20.03	322,225
2022	500	144	1,850	250	1,156,240	1,777,901	18,474	7,520	39,877	188,385	65,871	0.326	648,980	143,289	792,269	577,431	75%	0	0	127,871	126,517	312	35	24	254	2,787	48,045	1,061	85	22.46	327,016
2024	500	144	1,850	250	1,065,136	1,680,882	16,666	7,523	41,055	178,105	65,244	0.308	648,980	142,241	791,220	577,431	75%	0	0	126,742	125,857	311	34	23	253	2,772	47,794	1,062	85	22.46	327,315
2026	500	144	1,850	250	1,002,285	1,616,820	15,155	7,541	42,420	171,317	65,116	0.297	648,980	142,346	791,325	577,431	75%	0	0	126,857	126,078	311	34	23	253	2,777	47,878	1,067	85	22.46	327,275
2028	500	144	1,850	250	961,926	1,576,615	13,974	7,541	43,617	167,057	65,132	0.289	648,980	142,346	791,325	577,431	75%	0	0	126,857	126,078	311	34	23	253	2,777	47,878	1,067	85	22.46	327,275
2030	500	144	1,850	250	921,708	1,538,351	13,032	7,541	44,766	163,003	65,339	0.282	648,980	142,346	791,325	577,431	75%	0	0	126,857	126,078	311	34	23	253	2,777	47,878	1,067	85	22.46	327,275
2032	500	144	1,850	250	913,883	1,539,405	12,728	7,541	46,011	163,114	66,280	0.282	648,980	142,346	791,325	577,431	75%	0	0	126,857	126,078	311	34	23	253	2,777	47,878	1,067	85	22.46	327,275
2034	500	144	1,850	250	903,222	1,543,386	12,508	7,541	47,782	163,536	67,831	0.283	648,980	142,346	791,325	577,431	75%	0	0	126,857	126,078	311	34	23	253	2,777	47,878	1,067	85	22.46	327,275
2036	500	144	1,850	250	893,671	1,542,561	12,332	7,541	48,883	163,449	68,756	0.283	648,980	142,346	791,325	577,431	75%	0	0	126,857	126,078	311	34	23	253	2,777	47,878	1,067	85	22.46	327,275
2038	500	144	1,850	250	889,693	1,547,511	12,176	7,541	49,984	163,973	69,702	0.284	648,980	142,346	791,325	577,431	75%	0	0	126,857	126,078	311	34	23	253	2,777	47,878	1,067	85	22.46	327,275
2040	500	144	1,850	250	880,956	1,554,618	12,035	7,545	51,801	164,726	71,381	0.285	648,980	142,288	791,268	577,431	75%	0	0	126,799	126,071	311	34	23	253	2,777	47,875	1,068	85	22.46	327,279
2042	500	144	1,850	250	876,960	1,535,147	11,880	7,545	50,317	162,663	69,741	0.282	648,980	142,288	791,268	577,431	75%	0	0	126,799	126,071	311	34	23	253	2,777	47,875	1,068	85	22.46	327,279
2044	500	144	1,850	250	868,075	1,532,523	11,729	7,545	51,130	162,385	70,404	0.281	648,980	142,288	791,268	577,431	75%	0	0	126,799	126,071	311	34	23	253	2,777	47,875	1,068	85	22.46	327,279
2046	500	144	1,850	250	864,338	1,535,539	11,583	7,545	51,992	162,705	71,120	0.282	648,980	142,288	791,268	577,431	75%	0	0	126,799	126,071	311	34	23	253	2,777	47,875	1,068	85	22.46	327,279
2048	500	144	1,850	250	855,694	1,533,143	11,383	7,545	52,854	162,451	71,782	0.281	648,980	142,288	791,268	577,431	75%	0	0	126,799	126,071	311	34	23	253	2,777	47,875	1,068	85	22.46	327,279
2050	500	144	1,850	250	852,179	1,536,017	11,246	7,545	53,668	162,755	72,459	0.282	648,980	142,288	791,268	577,431	75%	0	0	126,799	126,071	311	34	23	253	2,777	47,875	1,068	85	22.46	327,279
Sunshot	500	144	1,900	250	615,602	1,118,317	8,240	7,584	37,444	118,496	53,267	0.205	648,980	140,443	789,423	577,431	76%	0	0	124,467	124,340	307	34	23	250	2,739	47,218	1,051	84	23.06	329,111

Accelerated Technology Improvement - Westchester Commercial (with Genset)

																					Emissions										
Battery Projection Study	PV	Diesel Genset	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Annual Cost	Operating Cost	COE	PV Production	Genset Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	CO2	CO	UHC	PM	SO2	NOx	Genset Fuel	Genset Hours	Genset Starts	Battery Autonomy	Battery Throughput
	kW	kW	Quantity	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	L/yr	hr/yr	starts/yr	hr	kWh/yr
Bloomberg New Energy Finance	750	144	1,600	250	1,040,432	1,832,774	19,014	6,019	27,853	122,331	52,886	0.212	973,471	104,416	1,077,887	577,431	0.82	0	0	415,591	92,493	228	25	17	186	2,037	35,124	783	75	19.42	318,661
Deutsche Bank	750	144	1,600	250	903,824	1,606,376	12,885	6,066	27,942	107,220	46,893	0.186	973,471	104,265	1,077,736	577,431	0.82	0	0	415,423	92,788	229	25	17	186	2,044	35,236	796	75	19.42	318,723
McKinsey	650	144	1,750	200	793,593	1,524,077	11,691	6,632	30,434	101,727	48,757	0.176	843,675	113,425	957,100	577,431	0.8	0	0	293,714	101,063	249	28	19	203	2,226	38,378	870	73	21.24	322,719
Department of Energy	600	144	2,600	300	748,482	1,367,292	10,303	7,572	23,429	91,262	41,304	0.158	778,777	87,811	866,588	577,431	0.85	0	0	198,265	77,800	192	21	14	156	1,714	29,544	659	43	31.56	339,766
Battery OEM	600	144	2,600	300	709,222	1,301,344	8,521	7,572	23,429	86,860	39,522	0.15	778,777	87,811	866,588	577,431	0.85	0	0	198,265	77,800	192	21	14	156	1,714	29,544	659	43	31.56	339,766

Demand-side Improvement - Westchester Commercial (with Genset)

																						Emissions										
Year	PV	Diesel Genset	1kWh Li-ion	Converter	Efficiency Case	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Annual Cost	Operating Cost	COE	PV Production	Genset Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	CO2	CO	UHC	PM	SO2	NOx	Genset Fuel	Genset Hours	Genset Starts	Battery Autonomy	Battery Throughput
	kW	kW	Quantity	kW		$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	L/yr	hr/yr	starts/yr	hr	kWh/yr
2014	400	144	1,000	150	Yes	987,327	1,538,371	25,180	4,470	28,739	163,005	58,388	0.428	519,184	94,436	613,620	381,104	75%	0	0	173,755	82,980	205	23	15	167	1,828	31,512	686	110	12.14	219,982
2016	400	144	1,100	150	Yes	884,282	1,368,719	20,602	4,590	22,932	135,972	48,125	0.357	519,184	91,060	610,245	381,104	76%	0	0	170,811	80,091	198	22	15	161	1,764	30,414	664	95	13.35	219,003
2018	400	144	1,100	150	Yes	1,032,030	1,715,342	20,353	4,590	23,054	120,491	47,998	0.316	519,184	91,060	610,245	381,104	76%	0	0	170,811	80,091	198	22	15	161	1,764	30,414	664	95	13.35	219,003
2020	400	144	1,100	150	Yes	933,933	1,646,487	18,842	4,616	24,103	109,897	47,561	0.288	519,184	90,661	609,845	381,104	76%	0	0	170,363	80,040	198	22	15	161	1,763	30,395	671	95	13.35	219,181
2022	400	144	1,100	150	Yes	858,157	1,567,804	17,498	4,644	25,224	104,646	47,367	0.275	519,184	90,275	609,459	381,104	76%	0	0	170,143	80,029	198	22	15	161	1,763	30,391	679	94	13.35	218,979
2024	400	144	1,100	150	Yes	794,730	1,497,361	16,241	4,644	26,013	99,944	46,898	0.262	519,184	89,844	609,028	381,104	76%	0	0	169,762	79,745	197	22	15	160	1,756	30,283	679	93	13.35	218,791
2026	400	144	1,100	150	Yes	752,224	1,451,236	15,196	4,655	26,806	96,865	46,657	0.254	519,184	89,594	608,778	381,104	76%	0	0	169,462	79,671	197	22	15	160	1,755	30,255	682	93	13.35	218,976
2028	450	144	1,150	150	Yes	791,671	1,419,135	14,215	4,392	23,275	94,722	41,881	0.249	584,083	75,421	659,504	381,104	80%	0	0	220,366	67,277	166	18	13	135	1,482	25,548	581	77	13.96	218,607
2030	450	144	1,200	150	Yes	769,433	1,387,910	13,775	4,398	23,109	92,638	41,281	0.243	584,083	73,286	657,369	381,104	81%	0	0	217,996	65,083	161	18	12	131	1,433	24,715	555	69	14.57	219,476
2032	450	144	1,200	150	Yes	764,357	1,389,018	13,545	4,398	23,751	92,712	41,694	0.243	584,083	73,286	657,369	381,104	81%	0	0	217,996	65,083	161	18	12	131	1,433	24,715	555	69	14.57	219,476
2034	450	144	1,200	150	Yes	756,185	1,392,053	13,378	4,398	24,666	92,915	42,442	0.244	584,083	73,286	657,369	381,104	81%	0	0	217,996	65,083	161	18	12	131	1,433	24,715	555	69	14.57	219,476
2036	450	144	1,200	150	Yes	748,733	1,391,117	13,245	4,398	25,234	92,852	42,877	0.244	584,083	73,286	657,369	381,104	81%	0	0	217,996	65,083	161	18	12	131	1,433	24,715	555	69	14.57	219,476
2038	450	144	1,200	150	Yes	746,153	1,395,294	13,128	4,398	25,802	93,131	43,328	0.244	584,083	73,286	657,369	381,104	81%	0	0	217,996	65,083	161	18	12	131	1,433	24,715	555	69	14.57	219,476
2040	450	144	1,200	150	Yes	739,229	1,400,800	13,018	4,398	26,742	93,499	44,158	0.245	584,083	73,286	657,369	381,104	81%	0	0	217,996	65,083	161	18	12	131	1,433	24,715	555	69	14.57	219,476
2042	450	144	1,200	150	Yes	736,637	1,384,966	12,900	4,398	25,975	92,442	43,274	0.243	584,083	73,286	657,369	381,104	81%	0	0	217,996	65,083	161	18	12	131	1,433	24,715	555	69	14.57	219,476
2044	450	144	1,200	150	Yes	729,617	1,382,536	12,786	4,398	26,396	92,280	43,580	0.242	584,083	73,286	657,369	381,104	81%	0	0	217,996	65,083	161	18	12	131	1,433	24,715	555	69	14.57	219,476
2046	450	144	1,200	150	Yes	727,193	1,385,121	12,676	4,398	26,840	92,452	43,914	0.243	584,083	73,286	657,369	381,104	81%	0	0	217,996	65,083	161	18	12	131	1,433	24,715	555	69	14.57	219,476
2048	450	144	1,200	150	Yes	720,329	1,382,710	12,528	4,398	27,285	92,291	44,212	0.242	584,083	73,286	657,369	381,104	81%	0	0	217,996	65,083	161	18	12	131	1,433	24,715	555	69	14.57	219,476
2050	450	144	1,200	150	Yes	718,049	1,385,173	12,425	4,398	27,705	92,456	44,528	0.243	584,083	73,286	657,369	381,104	81%	0	0	217,996	65,083	161	18	12	131	1,433	24,715	555	69	14.57	219,476
Sunshot	450	144	1,600	200	Yes	556,645	1,030,161	11,320	4,752	15,534	68,760	31,606	0.18	584,083	58,496	642,579	381,104	85%	0	0	201,862	51,585	127	14	10	104	1,136	19,589	431	44	19.42	224,206

Combined Improvement - Westchester Commercial (with Genset)

																						Emissions										
Battery Projection Study	PV	Diesel Genset	1kWh Li-ion	Converter	Efficiency Case	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Annual Cost	Operating Cost	COE	PV Production	Genset Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	CO2	CO	UHC	PM	SO2	NOx	Genset Fuel	Genset Hours	Genset Starts	Battery Autonomy	Battery Throughput
	kW	kW	Quantity	kW		$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	L/yr	hr/yr	starts/yr	hr	kWh/yr
Bloomberg New Energy Finance	500	144	1,100	150	Yes	729,889	1,333,655	17,689	4,061	18,549	89,017	40,299	0.234	648,980	69,739	718,719	381,104	0.82	0	0	280,293	61,595	152	17	11	124	1,357	23,391	517	72	13.35	215,638
Deutsche Bank	500	144	1,100	150	Yes	635,971	1,178,743	13,456	4,094	18,678	78,677	36,228	0.206	648,980	69,978	718,958	381,104	0.82	0	0	280,555	62,025	153	17	12	125	1,366	23,554	526	72	13.35	215,554
McKinsey	500	144	1,100	150	Yes	602,718	1,122,908	11,949	4,094	18,678	74,950	34,721	0.197	648,980	69,978	718,958	381,104	0.82	0	0	280,555	62,025	153	17	12	125	1,366	23,554	526	72	13.35	215,554
Department of Energy	450	144	1,600	200	Yes	556,629	1,030,145	11,320	4,752	15,534	68,759	31,606	0.18	584,083	58,496	642,579	381,104	0.85	0	0	201,862	51,585	127	14	10	104	1,136	19,589	431	44	19.42	224,206
Battery OEM	450	144	1,600	200	Yes	532,469	989,561	10,224	4,752	15,534	66,050	30,509	0.173	584,083	58,496	642,579	381,104	0.85	0	0	201,862	51,585	127	14	10	104	1,136	19,589	431	44	19.42	224,206

ROCKY MOUNTAIN INSTITUTE®

COMMERCIAL TABLES - LOUISVILLE, KY

Base Case - Louisville Commercial (with Genset)

Year	PV	Diesel Genset	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Annual Cost	Operating Cost	COE	PV Production	Genset Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Emissions CO2	CO	UHC	PM	SO2	NOx	Genset Fuel	Genset Hours	Genset Starts	Battery Autonomy	Battery Throughput
	kW	kW	Quantity	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	L/yr	hr/yr	starts/yr	hr	kWh/yr
2014	500	150	1,750	250	1,366,818	2,140,003	29,431	7,351	45,144	226,753	81,926	0.375	679,488	148,704	828,193	604,809	75%	0	0	132,286	130,350	322	36	24	262	2,871	49,500	1,027	99	20.28	342,389
2016	500	150	1,750	250	1,179,763	1,884,890	25,353	7,355	37,341	187,249	70,049	0.31	679,488	148,750	828,238	604,809	75%	0	0	132,325	130,412	322	36	24	262	2,872	49,523	1,028	99	20.28	342,413
2018	550	150	1,700	200	1,436,711	2,368,351	24,086	7,030	34,325	166,360	65,441	0.275	747,436	134,672	882,108	604,809	78%	0	0	186,244	119,248	294	33	22	239	2,626	45,284	968	95	19.7	341,262
2020	550	150	1,700	250	1,303,652	2,279,451	21,923	7,034	36,175	152,146	65,131	0.252	747,436	135,960	883,396	604,809	78%	0	0	188,013	120,127	297	33	22	241	2,646	45,618	969	90	19.7	339,205
2022	550	150	1,700	250	1,193,680	2,163,507	19,783	7,045	37,904	144,407	64,733	0.239	747,436	136,015	883,451	604,809	78%	0	0	188,029	120,258	297	33	22	241	2,649	45,668	972	90	19.7	339,355
2024	600	150	1,750	250	1,172,453	2,058,506	17,771	6,763	34,608	137,398	59,141	0.227	815,386	119,393	934,778	604,809	80%	0	0	239,081	106,092	262	29	20	213	2,337	40,288	870	80	20.28	340,726
2026	650	150	1,900	250	1,190,603	1,987,663	16,523	6,556	30,122	132,670	53,201	0.219	883,335	100,710	984,045	604,809	83%	0	0	287,697	89,526	221	24	17	180	1,972	33,997	735	62	22.02	343,153
2028	650	150	2,050	250	1,168,918	1,931,409	15,796	6,628	28,470	128,915	50,894	0.213	883,335	92,652	975,988	604,809	85%	0	0	279,022	82,294	203	23	15	165	1,813	31,251	674	53	23.76	345,554
2030	650	150	2,050	250	1,121,744	1,877,350	14,587	6,628	29,220	125,307	50,434	0.207	883,335	92,652	975,988	604,809	85%	0	0	279,022	82,294	203	23	15	165	1,813	31,251	674	53	23.76	345,554
2032	650	150	2,050	250	1,113,073	1,874,968	14,194	6,628	30,032	125,148	50,854	0.207	883,335	92,652	975,988	604,809	85%	0	0	279,022	82,294	203	23	15	165	1,813	31,251	674	53	23.76	345,554
2034	650	150	2,050	250	1,100,300	1,875,259	13,910	6,628	31,189	125,167	51,726	0.207	883,335	92,652	975,988	604,809	85%	0	0	279,022	82,294	203	23	15	165	1,813	31,251	674	53	23.76	345,554
2036	650	150	2,050	250	1,088,757	1,871,068	13,682	6,628	31,907	124,887	52,217	0.206	883,335	92,652	975,988	604,809	85%	0	0	279,022	82,294	203	23	15	165	1,813	31,251	674	53	23.76	345,554
2038	650	150	2,050	250	1,084,349	1,874,424	13,481	6,628	32,626	125,111	52,735	0.207	883,335	92,652	975,988	604,809	85%	0	0	279,022	82,294	203	23	15	165	1,813	31,251	674	53	23.76	345,554
2040	650	150	2,300	300	1,110,648	1,877,085	14,529	6,828	29,800	125,289	51,157	0.207	883,335	81,656	964,992	604,809	86%	0	0	265,960	72,527	179	20	13	146	1,597	27,542	594	46	26.66	350,977
2042	650	150	2,300	300	1,105,680	1,855,944	14,303	6,828	28,947	123,878	50,078	0.205	883,335	81,656	964,992	604,809	86%	0	0	265,960	72,527	179	20	13	146	1,597	27,542	594	46	26.66	350,977
2044	650	150	2,300	300	1,094,350	1,848,361	14,085	6,828	29,415	123,372	50,328	0.204	883,335	81,656	964,992	604,809	86%	0	0	265,960	72,527	179	20	13	146	1,597	27,542	594	46	26.66	350,977
2046	650	150	2,300	300	1,089,704	1,847,970	13,874	6,828	29,911	123,346	50,612	0.204	883,335	81,656	964,992	604,809	86%	0	0	265,960	72,527	179	20	13	146	1,597	27,542	594	46	26.66	350,977
2048	650	150	2,300	300	1,078,673	1,840,075	13,587	6,828	30,406	122,819	50,821	0.203	883,335	81,656	964,992	604,809	86%	0	0	265,960	72,527	179	20	13	146	1,597	27,542	594	46	26.66	350,977
2050	650	150	2,300	300	1,074,303	1,839,745	13,389	6,828	30,875	122,797	51,091	0.203	883,335	81,656	964,992	604,809	86%	0	0	265,960	72,527	179	20	13	146	1,597	27,542	594	46	26.66	350,977
Sunshot	650	150	2,300	300	766,834	1,330,149	8,931	6,828	21,841	88,783	37,599	0.147	883,335	81,656	964,992	604,809	86%	0	0	265,960	72,527	179	20	13	146	1,597	27,542	594	46	26.66	350,977

Base Case - Louisville Commercial (without Genset)

Year	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Annual Cost	Operating Cost	COE	PV Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Emissions CO2	CO	UHC	PM	SO2	NOx	Battery Autonomy	Battery Throughput
	kW	Quantity	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	hr	kWh/yr
2014	1,450	4,650	350	3,563,187	4,317,593	70,636	9,300	0	457,489	79,936	0.757	1,970,515	1,970,515	604,284	100%	605	524	1,275,460	0	0	0	0	0	0	53.89	342,268
2016	1,450	4,650	350	3,051,798	3,747,805	59,843	9,300	0	372,316	69,143	0.616	1,970,515	1,970,515	604,284	100%	605	524	1,275,460	0	0	0	0	0	0	53.89	342,268
2018	1,450	4,650	350	3,605,210	4,573,870	58,742	9,300	0	321,282	68,042	0.532	1,970,515	1,970,515	604,284	100%	605	524	1,275,460	0	0	0	0	0	0	53.89	342,268
2020	1,450	4,650	350	3,229,504	4,153,169	52,351	9,300	0	277,210	61,651	0.459	1,970,515	1,970,515	604,284	100%	605	524	1,275,460	0	0	0	0	0	0	53.89	342,268
2022	1,450	4,650	350	2,941,360	3,779,536	46,645	9,300	0	252,271	55,945	0.417	1,970,515	1,970,515	604,284	100%	605	524	1,275,460	0	0	0	0	0	0	53.89	342,268
2024	1,450	4,650	350	2,697,760	3,458,657	41,487	9,300	0	230,854	50,787	0.382	1,970,515	1,970,515	604,284	100%	605	524	1,275,460	0	0	0	0	0	0	53.89	342,268
2026	1,450	4,650	350	2,530,121	3,224,971	37,079	9,300	0	215,256	46,379	0.356	1,970,515	1,970,515	604,284	100%	605	524	1,275,460	0	0	0	0	0	0	53.89	342,268
2028	1,450	4,650	350	2,424,814	3,067,827	33,619	9,300	0	204,767	42,919	0.339	1,970,515	1,970,515	604,284	100%	605	524	1,275,460	0	0	0	0	0	0	53.89	342,268
2030	1,450	4,650	350	2,320,712	2,923,511	30,935	9,300	0	195,134	40,235	0.323	1,970,515	1,970,515	604,284	100%	605	524	1,275,460	0	0	0	0	0	0	53.89	342,268
2032	1,450	4,650	350	2,301,043	2,890,495	30,044	9,300	0	192,931	39,344	0.319	1,970,515	1,970,515	604,284	100%	605	524	1,275,460	0	0	0	0	0	0	53.89	342,268
2034	1,450	4,650	350	2,272,314	2,852,105	29,399	9,300	0	190,368	38,699	0.315	1,970,515	1,970,515	604,284	100%	605	524	1,275,460	0	0	0	0	0	0	53.89	342,268
2036	1,000	6,600	450	2,008,338	2,816,425	40,737	13,200	0	187,987	53,937	0.311	1,358,977	1,358,977	604,318	100%	575	491	660,660	0	0	0	0	0	0	76.49	357,125
2038	1,000	6,600	450	1,994,148	2,792,560	40,091	13,200	0	186,394	53,291	0.308	1,358,977	1,358,977	604,318	100%	575	491	660,660	0	0	0	0	0	0	76.49	357,125
2040	1,000	6,600	450	1,970,816	2,760,204	39,489	13,200	0	184,234	52,689	0.305	1,358,977	1,358,977	604,318	100%	575	491	660,660	0	0	0	0	0	0	76.49	357,125
2042	1,000	6,600	450	1,956,560	2,736,247	38,841	13,200	0	182,635	52,041	0.302	1,358,977	1,358,977	604,318	100%	575	491	660,660	0	0	0	0	0	0	76.49	357,125
2044	1,000	6,600	450	1,932,700	2,703,010	38,216	13,200	0	180,417	51,416	0.299	1,358,977	1,358,977	604,318	100%	575	491	660,660	0	0	0	0	0	0	76.49	357,125
2046	1,000	6,600	450	1,919,368	2,680,573	37,608	13,200	0	178,919	50,808	0.296	1,358,977	1,358,977	604,318	100%	575	491	660,660	0	0	0	0	0	0	76.49	357,125
2048	1,000	6,600	450	1,896,366	2,646,943	36,898	13,200	0	176,674	50,098	0.292	1,358,977	1,358,977	604,318	100%	575	491	660,660	0	0	0	0	0	0	76.49	357,125
2050	1,000	6,600	450	1,883,826	2,625,867	36,329	13,200	0	175,268	49,529	0.29	1,358,977	1,358,977	604,318	100%	575	491	660,660	0	0	0	0	0	0	76.49	357,125
Sunshot	1,000	6,600	450	1,294,828	1,855,354	24,213	13,200	0	123,839	37,413	0.205	1,358,977	1,358,977	604,318	100%	575	491	660,660	0	0	0	0	0	0	76.49	357,125

Accelerated Technology Improvement - Louisville Commercial (with Genset)

Battery Projection Study	PV	Diesel Genset	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Annual Cost	Operating Cost	COE	PV Production	Genset Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Emissions CO2	CO	UHC	PM	SO2	NOx	Genset Fuel	Genset Hours	Genset Starts	Battery Autonomy	Battery Throughput
	kW	kW	Quantity	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	L/yr	hr/yr	starts/yr	hr	kWh/yr
Bloomberg New Energy Finance	750	150	1,700	250	1,067,084	1,822,651	19,565	5,943	24,924	121,656	50,432	0.201	1,019,231	93,177	1,112,408	604,809	0.85	0	0	417,290	82,766	204	23	15	166	1,823	31,430	678	63	19.7	337,851
Deutsche Bank	750	150	1,700	250	921,938	1,581,569	13,040	5,980	25,008	105,564	44,028	0.175	1,019,231	93,119	1,112,350	604,809	0.85	0	0	417,184	83,044	205	23	15	167	1,829	31,536	688	63	19.7	338,029
McKinsey	700	150	1,850	200	846,684	1,493,629	11,470	6,359	25,353	99,695	43,181	0.165	951,283	93,852	1,045,135	604,809	0.84	0	0	349,273	84,190	208	23	16	169	1,854	31,971	709	60	21.44	341,034
Department of Energy	650	150	2,300	300	766,811	1,330,126	8,931	6,828	21,841	88,781	37,599	0.147	883,335	81,656	964,992	604,809	0.86	0	0	265,960	72,527	179	20	13	146	1,597	27,542	594	46	26.66	350,977
Battery OEM	700	150	2,700	250	790,269	1,266,643	7,892	7,125	16,779	84,544	31,796	0.14	951,283	62,556	1,013,839	604,809	0.9	0	0	315,562	55,719	138	15	10	112	1,227	21,159	460	31	31.29	354,387

Demand-side Improvement - Louisville Commercial (with Genset)

Year	PV	Diesel Genset	1kWh Li-ion	Converter	Efficiency Case	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Annual Cost	Operating Cost	COE	PV Production	Genset Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Emissions CO2	CO	UHC	PM	SO2	NOx	Genset Fuel	Genset Hours	Genset Starts	Battery Autonomy	Battery Throughput
	kW	kW	Quantity	kW		$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	L/yr	hr/yr	starts/yr	hr	kWh/yr
2014	350	150	1,150	150	Yes	959,542	1,526,734	24,880	4,933	30,287	161,772	60,099	0.405	475,642	99,143	574,784	399,174	75%	0	0	113,764	87,452	216	24	16	176	1,926	33,210	702	101	13.33	232,943
2016	350	150	1,150	150	Yes	833,263	1,357,403	22,097	4,933	25,040	134,848	52,069	0.338	475,642	99,143	574,784	399,174	75%	0	0	113,764	87,452	216	24	16	176	1,926	33,210	702	101	13.33	232,943
2018	350	150	1,200	150	Yes	983,287	1,707,946	21,897	4,928	24,078	119,971	50,902	0.301	475,642	94,706	570,348	399,174	76%	0	0	108,989	83,647	206	23	16	168	1,842	31,765	674	94	13.91	234,199
2020	400	150	1,200	150	Yes	960,863	1,648,517	19,796	4,654	21,449	110,033	45,899	0.276	543,590	79,344	622,934	399,174	80%	0	0	161,581	71,226	176	19	13	143	1,569	27,048	601	83	13.91	233,861
2022	400	150	1,200	150	Yes	882,471	1,563,118	18,314	4,669	22,448	104,333	45,431	0.261	543,590	79,143	622,733	399,174	80%	0	0	161,392	71,220	176	19	13	143	1,569	27,046	605	83	13.91	233,817
2024	450	150	1,200	150	Yes	878,187	1,487,815	16,654	4,298	19,740	99,307	40,691	0.249	611,540	67,631	679,170	399,174	83%	0	0	218,288	60,513	149	17	11	122	1,333	22,980	506	68	13.91	231,779
2026	450	150	1,200	150	Yes	831,135	1,433,584	15,505	4,305	20,401	95,687	40,211	0.24	611,540	67,721	679,260	399,174	83%	0	0	218,384	60,636	150	17	11	122	1,336	23,026	508	68	13.91	231,754
2028	450	150	1,200	150	Yes	802,443	1,400,139	14,612	4,305	20,977	93,455	39,894	0.234	611,540	67,721	679,260	399,174	83%	0	0	218,384	60,636	150	17	11	122	1,336	23,026	508	68	13.91	231,754
2030	450	150	1,200	150	Yes	772,707	1,368,060	13,903	4,305	21,529	91,313	39,738	0.229	611,540	67,721	679,260	399,174	83%	0	0	218,384	60,636	150	17	11	122	1,336	23,026	508	68	13.91	231,754
2032	450	150	1,200	150	Yes	767,631	1,368,509	13,673	4,305	22,128	91,343	40,107	0.229	611,540	67,721	679,260	399,174	83%	0	0	218,384	60,636	150	17	11	122	1,336	23,026	508	68	13.91	231,754
2034	450	150	1,200	150	Yes	759,459	1,370,608	13,507	4,305	22,980	91,483	40,792	0.229	611,540	67,721	679,260	399,174	83%	0	0	218,384	60,636	150	17	11	122	1,336	23,026	508	68	13.91	231,754
2036	450	150	1,200	200	Yes	758,007	1,369,069	13,568	4,200	23,018	91,381	40,786	0.229	611,540	67,140	678,680	399,174	83%	0	0	217,810	59,368	147	16	11	119	1,308	22,545	480	65	13.91	231,729
2038	450	150	1,200	200	Yes	755,427	1,372,990	13,453	4,204	23,563	91,642	41,220	0.23	611,540	67,192	678,732	399,174	83%	0	0	217,870	59,434	147	16	11	119	1,309	22,570	481	65	13.91	231,701
2040	450	150	1,200	200	Yes	748,503	1,377,275	13,344	4,204	24,421	91,928	41,968	0.23	611,540	67,192	678,732	399,174	83%	0	0	217,870	59,434	147	16	11	119	1,309	22,570	481	65	13.91	231,701
2042	450	150	1,200	200	Yes	745,911	1,362,436	13,226	4,204	23,721	90,938	41,151	0.228	611,540	67,192	678,732	399,174	83%	0	0	217,870	59,434	147	16	11	119	1,309	22,570	481	65	13.91	231,701
2044	450	150	1,200	200	Yes	738,891	1,359,460	13,112	4,204	24,105	90,739	41,421	0.227	611,540	67,192	678,732	399,174	83%	0	0	217,870	59,434	147	16	11	119	1,309	22,570	481	65	13.91	231,701
2046	400	150	1,650	200	Yes	734,833	1,361,100	15,256	4,916	21,629	90,849	41,801	0.228	543,590	58,978	602,568	399,174	85%	0	0	139,627	52,447	129	14	10	105	1,155	19,917	431	46	19.12	239,102
2048	400	150	1,650	200	Yes	727,582	1,356,205	15,054	4,916	21,988	90,522	41,958	0.227	543,590	58,978	602,568	399,174	85%	0	0	139,627	52,447	129	14	10	105	1,155	19,917	431	46	19.12	239,102
2050	400	150	1,650	200	Yes	724,447	1,356,008	14,912	4,916	22,326	90,509	42,155	0.227	543,590	58,978	602,568	399,174	85%	0	0	139,627	52,447	129	14	10	105	1,155	19,917	431	46	19.12	239,102
Sunshot	400	150	1,650	200	Yes	525,698	1,011,853	11,739	4,916	15,794	67,538	32,449	0.169	543,590	58,978	602,568	399,174	85%	0	0	139,627	52,447	129	14	10	105	1,155	19,917	431	46	19.12	239,102

Combined Improvement - Louisville Commercial (with Genset)

Battery Projection Study	PV	Diesel Genset	1kWh Li-ion	Converter	Efficiency Case	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Annual Cost	Operating Cost	COE	PV Production	Genset Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Emissions CO2	CO	UHC	PM	SO2	NOx	Genset Fuel	Genset Hours	Genset Starts	Battery Autonomy	Battery Throughput
	kW	kW	Quantity	kW		$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	L/yr	hr/yr	starts/yr	hr	kWh/yr
Bloomberg New Energy Finance	500	150	1,150	150	Yes	744,989	1,329,917	18,307	4,006	16,729	88,767	39,042	0.222	679,488	62,541	742,030	399,174	0.84	0	0	281,805	55,551	137	15	10	112	1,224	21,095	455	63	13.33	229,004
Deutsche Bank	500	150	1,150	150	Yes	646,802	1,165,919	13,876	4,033	16,741	77,821	34,649	0.195	679,488	62,267	741,756	399,174	0.84	0	0	281,520	55,592	137	15	10	112	1,224	21,111	462	63	13.33	229,045
McKinsey	450	150	1,200	200	Yes	584,083	1,106,680	12,803	4,200	17,878	73,867	34,882	0.185	611,540	67,140	678,680	399,174	0.83	0	0	217,810	59,368	147	16	11	119	1,308	22,545	480	65	13.91	231,729
Department of Energy	400	150	1,650	200	Yes	525,681	1,011,836	11,739	4,916	15,794	67,537	32,449	0.169	543,590	58,978	602,568	399,174	0.85	0	0	139,627	52,447	129	14	10	105	1,155	19,917	431	46	19.12	239,102
Battery OEM	450	150	2,000	200	Yes	559,931	966,154	11,175	5,099	10,840	64,488	27,114	0.162	611,540	40,613	652,153	399,174	0.9	0	0	189,901	35,996	89	10	7	72	793	13,669	293	28	23.18	239,535

COMMERCIAL TABLES - SAN ANTONIO, TX

Base Case - San Antonio Commercial (with Genset)

Year	PV	Diesel Genset	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Annual Cost	Operating Cost	COE	PV Production	Genset Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Emissions CO2	CO	UHC	PM	SO2	NOx	Genset Fuel	Genset Hours	Genset Starts	Battery Autonomy	Battery Throughput
	kW	kW	Quantity	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	L/yr	hr/yr	starts/yr	hr	kWh/yr
2014	550	156	1,900	250	1,487,759	2,121,217	30,127	6,460	30,534	224,763	67,121	0.335	853,328	99,874	953,201	670,504	85%	0	0	182,318	88,164	218	24	16	177	1,942	33,480	682	66	19.86	375,537
2016	550	156	1,900	250	1,283,885	1,861,155	25,664	6,460	25,223	184,891	57,347	0.276	853,328	99,764	953,092	670,504	85%	0	0	182,207	88,092	217	24	16	177	1,940	33,453	682	66	19.86	375,542
2018	550	156	1,900	250	1,502,177	2,315,300	25,299	6,460	25,357	162,634	57,116	0.243	853,328	99,764	953,092	670,504	85%	0	0	182,207	88,092	217	24	16	177	1,940	33,453	682	66	19.86	375,542
2020	600	156	1,850	250	1,413,636	2,179,780	22,190	6,067	22,880	145,493	51,138	0.217	930,904	85,109	1,016,012	670,504	87%	0	0	245,888	75,979	188	21	14	153	1,673	28,853	607	57	19.34	374,491
2022	600	156	1,850	250	1,294,240	2,041,414	19,847	6,079	23,945	136,257	49,871	0.203	930,904	84,947	1,015,851	670,504	87%	0	0	245,654	75,971	188	21	14	153	1,673	28,850	610	57	19.34	374,760
2024	600	156	1,850	250	1,194,136	1,921,351	17,678	6,079	24,782	128,244	48,539	0.191	930,904	84,947	1,015,851	670,504	87%	0	0	245,654	75,971	188	21	14	153	1,673	28,850	610	57	19.34	374,760
2026	600	156	1,850	250	1,126,285	1,838,286	15,852	6,083	25,589	122,699	47,524	0.183	930,904	85,023	1,015,927	670,504	87%	0	0	245,729	76,054	188	21	14	153	1,675	28,881	611	57	19.34	374,766
2028	600	156	1,850	250	1,083,926	1,785,537	14,436	6,083	26,311	119,179	46,830	0.178	930,904	85,023	1,015,927	670,504	87%	0	0	245,729	76,054	188	21	14	153	1,675	28,881	611	57	19.34	374,766
2030	600	156	1,900	250	1,047,592	1,735,782	13,269	6,167	26,498	115,858	45,934	0.173	930,904	83,057	1,013,961	670,504	88%	0	0	243,351	74,628	184	20	14	150	1,644	28,340	607	57	19.86	376,290
2032	600	156	2,250	250	1,086,263	1,729,231	14,639	6,392	21,885	115,420	42,916	0.172	930,904	66,881	997,785	670,504	90%	0	0	225,949	59,969	148	16	11	120	1,321	22,773	485	41	23.52	383,031
2034	600	156	2,250	250	1,073,378	1,724,295	14,327	6,392	22,728	115,091	43,447	0.172	930,904	66,881	997,785	670,504	90%	0	0	225,949	59,969	148	16	11	120	1,321	22,773	485	41	23.52	383,031
2036	600	156	2,250	250	1,061,843	1,716,857	14,077	6,392	23,251	114,594	43,720	0.171	930,904	66,881	997,785	670,504	90%	0	0	225,949	59,969	148	16	11	120	1,321	22,773	485	41	23.52	383,031
2038	600	156	2,250	250	1,057,005	1,716,569	13,857	6,392	23,775	114,575	44,024	0.171	930,904	66,881	997,785	670,504	90%	0	0	225,949	59,969	148	16	11	120	1,321	22,773	485	41	23.52	383,031
2040	600	156	2,250	300	1,052,460	1,715,719	13,852	6,294	24,125	114,518	44,270	0.171	930,904	66,222	997,125	670,504	90%	0	0	225,211	58,714	145	16	11	118	1,293	22,296	460	39	23.52	383,322
2042	600	156	2,250	250	1,041,600	1,697,168	13,431	6,392	23,935	113,280	43,757	0.169	930,904	66,881	997,785	670,504	90%	0	0	225,949	59,969	148	16	11	120	1,321	22,773	485	41	23.52	383,031
2044	600	156	2,250	300	1,036,875	1,688,953	13,418	6,294	23,812	112,732	43,524	0.168	930,904	66,222	997,125	670,504	90%	0	0	225,211	58,714	145	16	11	118	1,293	22,296	460	39	23.52	383,322
2046	600	156	2,250	300	1,032,330	1,687,317	13,210	6,294	24,214	112,623	43,718	0.168	930,904	66,222	997,125	670,504	90%	0	0	225,211	58,714	145	16	11	118	1,293	22,296	460	39	23.52	383,322
2048	650	156	2,650	300	1,122,102	1,676,008	14,582	6,513	15,876	111,868	36,971	0.167	1,008,478	41,998	1,050,476	670,504	94%	0	0	277,152	37,870	93	10	7	76	834	14,381	311	27	27.7	387,795
2050	650	156	2,650	300	1,117,067	1,671,209	14,353	6,513	16,121	111,548	36,987	0.166	1,008,478	41,998	1,050,476	670,504	94%	0	0	277,152	37,870	93	10	7	76	834	14,381	311	27	27.7	387,795
Sunshot	650	156	2,650	300	796,287	1,203,939	9,292	6,513	11,404	80,359	27,209	0.12	1,008,478	41,998	1,050,476	670,504	94%	0	0	277,152	37,870	93	10	7	76	834	14,381	311	27	27.7	387,795

Base Case - San Antonio Commercial (without Genset)

Year	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Annual Cost	Operating Cost	COE	PV Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Emissions CO2	CO	UHC	PM	SO2	NOx	Battery Autonomy	Battery Throughput
	kW	Quantity	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	hr	kWh/yr
2014	950	3,500	300	2,477,135	3,047,806	53,468	7,000	0	322,944	60,468	0.482	1,473,928	1,473,928	669,934	100%	649	570	702,246	0	0	0	0	0	0	36.59	380,876
2016	950	3,500	300	2,115,525	2,642,175	45,319	7,000	0	262,480	52,319	0.392	1,473,928	1,473,928	669,934	100%	649	570	702,246	0	0	0	0	0	0	36.59	380,876
2018	950	3,500	300	2,496,405	3,229,467	44,492	7,000	0	226,847	51,492	0.339	1,473,928	1,473,928	669,934	100%	649	570	702,246	0	0	0	0	0	0	36.59	380,876
2020	950	3,500	300	2,234,460	2,933,594	39,665	7,000	0	195,807	46,665	0.292	1,473,928	1,473,928	669,934	100%	649	570	702,246	0	0	0	0	0	0	36.59	380,876
2022	950	3,500	300	2,032,400	2,666,888	35,350	7,000	0	178,006	42,350	0.266	1,473,928	1,473,928	669,934	100%	649	570	702,246	0	0	0	0	0	0	36.59	380,876
2024	950	3,500	300	1,861,405	2,437,426	31,447	7,000	0	162,690	38,447	0.243	1,473,928	1,473,928	669,934	100%	649	570	702,246	0	0	0	0	0	0	36.59	380,876
2026	950	3,500	300	1,742,295	2,268,453	28,119	7,000	0	151,412	35,119	0.226	1,473,928	1,473,928	669,934	100%	649	570	702,246	0	0	0	0	0	0	36.59	380,876
2028	950	3,500	300	1,665,860	2,153,001	25,515	7,000	0	143,706	32,515	0.215	1,473,928	1,473,928	669,934	100%	649	570	702,246	0	0	0	0	0	0	36.59	380,876
2030	950	3,500	300	1,591,380	2,048,102	23,485	7,000	0	136,704	30,485	0.204	1,473,928	1,473,928	669,934	100%	649	570	702,246	0	0	0	0	0	0	36.59	380,876
2032	950	3,500	300	1,576,575	2,023,251	22,814	7,000	0	135,045	29,814	0.202	1,473,928	1,473,928	669,934	100%	649	570	702,246	0	0	0	0	0	0	36.59	380,876
2034	950	3,500	300	1,556,365	1,995,770	22,329	7,000	0	133,211	29,329	0.199	1,473,928	1,473,928	669,934	100%	649	570	702,246	0	0	0	0	0	0	36.59	380,876
2036	950	3,500	300	1,538,255	1,971,825	21,939	7,000	0	131,613	28,939	0.196	1,473,928	1,473,928	669,934	100%	649	570	702,246	0	0	0	0	0	0	36.59	380,876
2038	950	3,500	300	1,530,730	1,959,170	21,597	7,000	0	130,768	28,597	0.195	1,473,928	1,473,928	669,934	100%	649	570	702,246	0	0	0	0	0	0	36.59	380,876
2040	950	3,500	300	1,514,160	1,937,814	21,277	7,000	0	129,343	28,277	0.193	1,473,928	1,473,928	669,934	100%	649	570	702,246	0	0	0	0	0	0	36.59	380,876
2042	950	3,500	300	1,506,600	1,925,109	20,934	7,000	0	128,495	27,934	0.192	1,473,928	1,473,928	669,934	100%	649	570	702,246	0	0	0	0	0	0	36.59	380,876
2044	950	3,500	300	1,489,750	1,903,287	20,602	7,000	0	127,038	27,602	0.19	1,473,928	1,473,928	669,934	100%	649	570	702,246	0	0	0	0	0	0	36.59	380,876
2046	950	3,500	300	1,482,680	1,891,388	20,280	7,000	0	126,244	27,280	0.188	1,473,928	1,473,928	669,934	100%	649	570	702,246	0	0	0	0	0	0	36.59	380,876
2048	950	3,500	300	1,466,285	1,869,106	19,887	7,000	0	124,756	26,887	0.186	1,473,928	1,473,928	669,934	100%	649	570	702,246	0	0	0	0	0	0	36.59	380,876
2050	950	3,500	300	1,459,635	1,857,929	19,585	7,000	0	124,010	26,585	0.185	1,473,928	1,473,928	669,934	100%	649	570	702,246	0	0	0	0	0	0	36.59	380,876
Sunshot	950	3,500	300	1,010,530	1,311,054	13,059	7,000	0	87,508	20,059	0.131	1,473,928	1,473,928	669,934	100%	649	570	702,246	0	0	0	0	0	0	36.59	380,876

Accelerated Technology Improvement - San Antonio Commercial (with Genset)

Battery Projection Study	PV	Diesel Genset	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Annual Cost	Operating Cost	COE	PV Production	Genset Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Emissions CO2	CO	UHC	PM	SO2	NOx	Genset Fuel	Genset Hours	Genset Starts	Battery Autonomy	Battery Throughput
	kW	kW	Quantity	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	L/yr	hr/yr	starts/yr	hr	kWh/yr
Bloomberg New Energy Finance	750	156	1,850	250	1,105,562	1,732,076	20,401	5,361	16,055	115,610	41,818	0.172	1,163,626	59,719	1,223,345	670,504	0.91	0	0	453,989	53,315	132	15	10	107	1,174	20,246	426	39	19.34	371,598
Deutsche Bank	750	156	1,850	250	947,609	1,465,299	13,175	5,361	16,018	97,804	34,554	0.146	1,163,626	59,531	1,223,157	670,504	0.91	0	0	453,792	53,191	131	15	10	107	1,172	20,199	426	39	19.34	371,630
McKinsey	750	156	1,850	250	891,684	1,371,025	10,615	5,361	16,018	91,511	31,994	0.136	1,163,626	59,531	1,223,157	670,504	0.91	0	0	453,792	53,191	131	15	10	107	1,172	20,199	426	39	19.34	371,630
Department of Energy	650	156	2,650	300	796,261	1,203,913	9,292	6,513	11,404	80,357	27,209	0.12	1,008,478	41,998	1,050,476	670,504	0.94	0	0	277,152	37,870	93	10	7	76	834	14,381	311	27	27.7	387,795
Battery OEM	650	156	2,650	300	756,246	1,136,696	7,477	6,513	11,404	75,871	25,394	0.113	1,008,478	41,998	1,050,476	670,504	0.94	0	0	277,152	37,870	93	10	7	76	834	14,381	311	27	27.7	387,795

Demand-side Improvement - San Antonio Commercial (with Genset)

Year	PV	Diesel Genset	1kWh Li-ion	Converter	Efficiency Case	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Annual Cost	Operating Cost	COE	PV Production	Genset Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Emissions CO2	CO	UHC	PM	SO2	NOx	Genset Fuel	Genset Hours	Genset Starts	Battery Autonomy	Battery Throughput
	kW	kW	Quantity	kW		$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	L/yr	hr/yr	starts/yr	hr	kWh/yr
2014	350	156	1,250	150	Yes	992,154	1,508,804	26,532	4,614	23,598	159,872	54,744	0.361	543,025	76,445	619,470	442,532	83%	0	0	109,187	68,139	168	19	13	137	1,501	25,876	542	76	13.07	253,499
2016	350	156	1,300	150	Yes	872,037	1,338,603	23,534	4,577	18,239	132,980	46,350	0.3	543,025	71,448	614,473	442,532	84%	0	0	104,079	63,699	157	17	12	128	1,403	24,189	507	68	13.59	253,909
2018	350	156	1,300	150	Yes	1,013,921	1,668,448	23,063	4,577	18,336	117,197	45,976	0.265	543,025	71,448	614,473	442,532	84%	0	0	104,079	63,699	157	17	12	128	1,403	24,189	507	68	13.59	253,909
2020	400	156	1,250	150	Yes	976,342	1,585,648	20,713	4,212	15,744	105,837	40,669	0.239	620,602	57,502	678,104	442,532	87%	0	0	168,342	52,283	129	14	10	105	1,152	19,854	439	59	13.07	251,920
2022	400	156	1,250	200	Yes	903,642	1,491,913	19,393	4,076	15,797	99,580	39,265	0.225	620,602	55,961	676,562	442,532	87%	0	0	166,686	50,118	124	14	9	101	1,104	19,032	404	57	13.07	252,344
2024	400	156	1,250	200	Yes	836,179	1,410,663	17,921	4,076	16,349	94,157	38,345	0.213	620,602	55,961	676,562	442,532	87%	0	0	166,686	50,118	124	14	9	101	1,104	19,032	404	57	13.07	252,344
2026	400	156	1,250	200	Yes	790,604	1,353,556	16,685	4,076	16,814	90,345	37,575	0.204	620,602	55,742	676,344	442,532	87%	0	0	166,459	49,974	123	14	9	100	1,101	18,978	404	57	13.07	252,378
2028	400	156	1,250	200	Yes	762,092	1,317,925	15,736	4,076	17,289	87,967	37,100	0.199	620,602	55,742	676,344	442,532	87%	0	0	166,459	49,974	123	14	9	100	1,101	18,978	404	57	13.07	252,378
2030	450	156	1,300	200	Yes	796,126	1,282,203	14,824	3,786	13,835	85,583	32,444	0.193	698,176	44,011	742,187	442,532	90%	0	0	233,102	38,964	96	11	7	78	858	14,797	304	40	13.59	250,778
2032	450	156	1,300	200	Yes	790,627	1,278,736	14,575	3,786	14,220	85,351	32,580	0.193	698,176	44,011	742,187	442,532	90%	0	0	233,102	38,964	96	11	7	78	858	14,797	304	40	13.59	250,778
2034	450	156	1,300	200	Yes	782,149	1,275,760	14,394	3,786	14,767	85,153	32,947	0.192	698,176	44,011	742,187	442,532	90%	0	0	233,102	38,964	96	11	7	78	858	14,797	304	40	13.59	250,778
2036	450	156	1,300	200	Yes	774,451	1,270,993	14,250	3,786	15,107	84,835	33,143	0.192	698,176	44,011	742,187	442,532	90%	0	0	233,102	38,964	96	11	7	78	858	14,797	304	40	13.59	250,778
2038	450	156	1,300	200	Yes	771,656	1,271,392	14,122	3,786	15,448	84,861	33,356	0.192	698,176	44,011	742,187	442,532	90%	0	0	233,102	38,964	96	11	7	78	858	14,797	304	40	13.59	250,778
2040	450	156	1,300	200	Yes	764,530	1,270,912	14,004	3,786	16,010	84,829	33,799	0.192	698,176	44,011	742,187	442,532	90%	0	0	233,102	38,964	96	11	7	78	858	14,797	304	40	13.59	250,778
2042	450	156	1,300	200	Yes	761,722	1,259,321	13,876	3,786	15,551	84,055	33,213	0.19	698,176	44,011	742,187	442,532	90%	0	0	233,102	38,964	96	11	7	78	858	14,797	304	40	13.59	250,778
2044	450	156	1,300	200	Yes	754,492	1,254,013	13,753	3,786	15,803	83,701	33,341	0.189	698,176	44,011	742,187	442,532	90%	0	0	233,102	38,964	96	11	7	78	858	14,797	304	40	13.59	250,778
2046	450	156	1,300	200	Yes	751,866	1,253,635	13,636	3,790	16,066	83,676	33,491	0.189	698,176	43,948	742,124	442,532	90%	0	0	233,036	38,956	96	11	7	78	858	14,793	305	40	13.59	250,792
2048	450	156	1,700	200	Yes	791,009	1,246,386	15,294	4,239	10,862	83,192	30,395	0.188	698,176	28,623	726,800	442,532	94%	0	0	216,374	25,909	64	7	5	52	571	9,839	215	25	17.77	255,745
2050	450	156	1,700	200	Yes	787,779	1,243,463	15,147	4,239	11,030	82,997	30,415	0.188	698,176	28,623	726,800	442,532	94%	0	0	216,374	25,909	64	7	5	52	571	9,839	215	25	17.77	255,745
Sunshot	450	156	1,700	200	Yes	571,128	929,636	11,888	4,239	7,802	62,050	23,929	0.14	698,176	28,623	726,800	442,532	94%	0	0	216,374	25,909	64	7	5	52	571	9,839	215	25	17.77	255,745

Combined Improvement - San Antonio Commercial (with Genset)

Battery Projection Study	PV	Diesel Genset	1kWh Li-ion	Converter	Efficiency Case	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Annual Cost	Operating Cost	COE	PV Production	Genset Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Emissions CO2	CO	UHC	PM	SO2	NOx	Genset Fuel	Genset Hours	Genset Starts	Battery Autonomy	Battery Throughput
	kW	kW	Quantity	kW		$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	L/yr	hr/yr	starts/yr	hr	kWh/yr
Bloomberg New Energy Finance	500	156	1,250	200	Yes	776,292	1,279,179	19,639	3,565	10,363	85,381	33,566	0.193	775,752	38,642	814,394	442,532	0.91	0	0	305,661	34,411	85	9	6	69	758	13,068	273	38	13.07	248,725
Deutsche Bank	450	156	1,300	200	Yes	639,124	1,099,882	15,235	3,786	11,734	73,413	30,754	0.166	698,176	44,011	742,187	442,532	0.9	0	0	233,102	38,964	96	11	7	78	858	14,797	304	40	13.59	250,778
McKinsey	450	156	1,300	200	Yes	599,825	1,033,894	13,453	3,786	11,734	69,009	28,973	0.156	698,176	44,011	742,187	442,532	0.9	0	0	233,102	38,964	96	11	7	78	858	14,797	304	40	13.59	250,778
Department of Energy	450	156	1,700	200	Yes	571,111	929,619	11,888	4,239	7,802	62,049	23,929	0.14	698,176	28,623	726,800	442,532	0.94	0	0	216,374	25,909	64	7	5	52	571	9,839	215	25	17.77	255,745
Battery OEM	450	156	1,900	200	Yes	557,535	885,727	11,130	4,451	6,325	59,119	21,906	0.134	698,176	23,565	721,742	442,532	0.95	0	0	211,097	21,002	52	6	4	42	463	7,976	167	17	19.86	256,555

COMMERCIAL TABLES - LOS ANGELES, CA

Base Case - Los Angeles Commercial (with Genset)

Year	PV	Diesel Genset	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Annual Cost	Operating Cost	COE	PV Production	Genset Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Emissions CO2	CO	UHC	PM	SO2	NOx	Genset Fuel	Genset Hours	Genset Starts	Battery Autonomy	Battery Throughput
	kW	kW	Quantity	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	L/yr	hr/yr	starts/yr	hr	kWh/yr
2014	400	115	1,650	200	1,163,357	1,803,469	27,153	6,279	34,394	191,095	67,826	0.326	642,870	112,728	755,598	586,557	81%	0	0	82,282	99,310	245	27	18	199	2,187	37,713	1,036	83	19.72	325,202
2016	400	115	1,650	200	999,848	1,582,078	23,309	6,270	28,261	157,167	57,840	0.268	642,870	111,912	754,782	586,557	81%	0	0	81,264	98,700	244	27	18	198	2,174	37,481	1,033	81	19.72	325,948
2018	450	115	1,600	200	1,234,228	1,989,878	22,794	5,767	24,518	139,775	53,079	0.238	723,228	96,522	819,749	586,557	84%	0	0	146,251	85,177	210	23	16	171	1,876	32,346	893	73	19.12	325,984
2020	450	115	1,650	200	1,123,324	1,888,832	20,324	5,879	24,892	126,073	51,095	0.215	723,228	92,551	815,778	586,557	84%	0	0	141,792	82,660	204	23	15	166	1,821	31,390	897	69	19.72	327,830
2022	450	115	1,650	200	1,026,660	1,778,922	18,276	5,893	26,042	118,737	50,211	0.202	723,228	92,309	815,537	586,557	84%	0	0	141,471	82,622	204	23	15	166	1,820	31,375	902	69	19.72	328,122
2024	500	115	1,700	200	1,016,111	1,679,991	16,263	5,571	22,478	112,134	44,312	0.191	803,588	76,887	880,475	586,557	87%	18	0	206,132	68,908	170	19	13	138	1,518	26,168	755	56	20.32	329,238
2026	500	115	1,700	200	956,329	1,606,352	14,632	5,571	23,184	107,219	43,387	0.183	803,588	76,887	880,475	586,557	87%	18	0	206,132	68,908	170	19	13	138	1,518	26,168	755	56	20.32	329,238
2028	500	115	1,700	200	918,432	1,559,305	13,367	5,571	23,839	104,078	42,776	0.177	803,588	76,887	880,475	586,557	87%	18	0	206,132	68,908	170	19	13	138	1,518	26,168	755	56	20.32	329,238
2030	550	115	1,850	200	957,708	1,513,486	12,645	5,428	19,024	101,020	37,096	0.172	883,945	59,267	943,212	586,557	90%	2	0	268,415	53,578	132	15	10	108	1,180	20,346	601	44	22.11	332,879
2032	550	115	1,900	250	962,555	1,507,826	12,740	5,364	18,291	100,642	36,395	0.172	883,945	56,112	940,057	586,557	90%	0	0	264,718	50,120	124	14	9	101	1,104	19,033	544	41	22.71	335,055
2034	550	115	1,900	250	951,241	1,503,115	12,477	5,364	18,995	100,328	36,836	0.171	883,945	56,112	940,057	586,557	90%	0	0	264,718	50,120	124	14	9	101	1,104	19,033	544	41	22.71	335,055
2036	550	115	1,900	250	941,067	1,496,332	12,265	5,364	19,433	99,875	37,062	0.17	883,945	56,112	940,057	586,557	90%	0	0	264,718	50,120	124	14	9	101	1,104	19,033	544	41	22.71	335,055
2038	550	115	1,900	250	936,982	1,496,020	12,080	5,364	19,870	99,854	37,314	0.17	883,945	56,112	940,057	586,557	90%	0	0	264,718	50,120	124	14	9	101	1,104	19,033	544	41	22.71	335,055
2040	550	115	1,900	250	927,644	1,494,920	11,906	5,364	20,594	99,781	37,864	0.17	883,945	56,112	940,057	586,557	90%	0	0	264,718	50,120	124	14	9	101	1,104	19,033	544	41	22.71	335,055
2042	550	115	1,900	250	923,540	1,479,184	11,720	5,364	20,004	98,731	37,087	0.168	883,945	56,112	940,057	586,557	90%	0	0	264,718	50,120	124	14	9	101	1,104	19,033	544	41	22.71	335,055
2044	550	115	1,900	250	914,050	1,471,842	11,540	5,364	20,327	98,240	37,231	0.167	883,945	56,112	940,057	586,557	90%	0	0	264,718	50,120	124	14	9	101	1,104	19,033	544	41	22.71	335,055
2046	550	115	2,150	250	939,582	1,469,584	12,515	5,625	17,236	98,090	35,376	0.167	883,945	46,518	930,463	586,557	92%	0	0	254,085	41,793	103	11	8	84	921	15,871	461	33	25.69	340,055
2048	550	115	2,150	250	929,847	1,460,242	12,255	5,625	17,521	97,466	35,402	0.166	883,945	46,518	930,463	586,557	92%	0	0	254,085	41,793	103	11	8	84	921	15,871	461	33	25.69	340,055
2050	600	115	2,100	250	974,081	1,457,265	11,671	5,339	15,242	97,267	32,251	0.166	964,304	39,813	1,004,117	586,557	93%	0	0	327,915	35,804	88	10	7	72	789	13,597	396	30	25.1	338,577
Sunshot	600	115	2,100	250	692,218	1,048,201	7,640	5,339	10,782	69,964	23,761	0.119	964,304	39,813	1,004,117	586,557	93%	0	0	327,915	35,804	88	10	7	72	789	13,597	396	30	25.1	338,577

Base Case - Los Angeles Commercial (without Genset)

Year	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Annual Cost	Operating Cost	COE	PV Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Emissions CO2	CO	UHC	PM	SO2	NOx	Battery Autonomy	Battery Throughput
	kW	Quantity	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	hr	kWh/yr
2014	750	4,100	300	2,352,901	3,017,408	62,211	8,200	0	319,723	70,411	0.546	1,205,378	1,205,378	586,092	100%	581	465	528,526	0	0	0	0	0	0	49	341,155
2016	750	4,100	300	1,992,015	2,605,047	52,700	8,200	0	258,791	60,900	0.442	1,205,378	1,205,378	586,092	100%	581	465	528,526	0	0	0	0	0	0	49	341,155
2018	750	4,100	300	2,342,303	3,195,458	51,728	8,200	0	224,459	59,928	0.383	1,205,378	1,205,378	586,092	100%	581	465	528,526	0	0	0	0	0	0	49	341,155
2020	750	4,100	300	2,090,396	2,903,892	46,098	8,200	0	193,825	54,298	0.331	1,205,378	1,205,378	586,092	100%	581	465	528,526	0	0	0	0	0	0	49	341,155
2022	750	4,100	300	1,894,640	2,632,830	41,072	8,200	0	175,732	49,272	0.3	1,205,378	1,205,378	586,092	100%	581	465	528,526	0	0	0	0	0	0	49	341,155
2024	750	4,100	300	1,727,503	2,397,625	36,528	8,200	0	160,033	44,728	0.273	1,205,378	1,205,378	586,092	100%	581	465	528,526	0	0	0	0	0	0	49	341,155
2026	750	4,100	300	1,606,117	2,218,039	32,644	8,200	0	148,047	40,844	0.253	1,205,378	1,205,378	586,092	100%	581	465	528,526	0	0	0	0	0	0	49	341,155
2028	750	4,100	300	1,523,836	2,090,052	29,593	8,200	0	139,504	37,793	0.238	1,205,378	1,205,378	586,092	100%	581	465	528,526	0	0	0	0	0	0	49	341,155
2030	750	4,100	300	1,447,988	1,978,782	27,229	8,200	0	132,077	35,429	0.225	1,205,378	1,205,378	586,092	100%	581	465	528,526	0	0	0	0	0	0	49	341,155
2032	750	4,100	300	1,430,645	1,949,671	26,443	8,200	0	130,134	34,643	0.222	1,205,378	1,205,378	586,092	100%	581	465	528,526	0	0	0	0	0	0	49	341,155
2034	750	4,100	300	1,410,599	1,921,107	25,875	8,200	0	128,227	34,075	0.219	1,205,378	1,205,378	586,092	100%	581	465	528,526	0	0	0	0	0	0	49	341,155
2036	750	4,100	300	1,393,013	1,896,686	25,418	8,200	0	126,597	33,618	0.216	1,205,378	1,205,378	586,092	100%	581	465	528,526	0	0	0	0	0	0	49	341,155
2038	750	4,100	300	1,384,198	1,881,861	25,017	8,200	0	125,608	33,217	0.214	1,205,378	1,205,378	586,092	100%	581	465	528,526	0	0	0	0	0	0	49	341,155
2040	750	4,100	300	1,368,416	1,860,473	24,643	8,200	0	124,180	32,843	0.212	1,205,378	1,205,378	586,092	100%	581	465	528,526	0	0	0	0	0	0	49	341,155
2042	750	4,100	300	1,359,560	1,845,590	24,241	8,200	0	123,187	32,441	0.21	1,205,378	1,205,378	586,092	100%	581	465	528,526	0	0	0	0	0	0	49	341,155
2044	750	4,100	300	1,343,450	1,823,656	23,852	8,200	0	121,723	32,052	0.208	1,205,378	1,205,378	586,092	100%	581	465	528,526	0	0	0	0	0	0	49	341,155
2046	750	4,100	300	1,335,168	1,809,717	23,475	8,200	0	120,793	31,675	0.206	1,205,378	1,205,378	586,092	100%	581	465	528,526	0	0	0	0	0	0	49	341,155
2048	750	4,100	300	1,319,591	1,787,454	23,028	8,200	0	119,307	31,228	0.204	1,205,378	1,205,378	586,092	100%	581	465	528,526	0	0	0	0	0	0	49	341,155
2050	750	4,100	300	1,311,801	1,774,361	22,674	8,200	0	118,433	30,874	0.202	1,205,378	1,205,378	586,092	100%	581	465	528,526	0	0	0	0	0	0	49	341,155
Sunshot	750	4,100	300	903,878	1,253,175	15,114	8,200	0	83,645	23,314	0.143	1,205,378	1,205,378	586,092	100%	581	465	528,526	0	0	0	0	0	0	49	341,155

Base Case - Los Angeles Fixed Cost of Capital (9.5%) with Genset

Year	PV	Diesel Genset	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Annual Cost	Operating Cost	COE	PV Production	Genset Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Emissions CO2	CO	UHC	PM	SO2	NOx	Genset Fuel	Genset Hours	Genset Starts	Battery Autonomy	Battery Throughput
	kW	kW	Quantity	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	L/yr	hr/yr	starts/yr	hr	kWh/yr
2014	400	115	1,650	200	1,163,357	1,803,469	27,153	6,279	34,394	191,095	67,826	0.326	642,870	112,728	755,598	586,557	81%	0	0	82,282	99,310	245	27	18	199	2,187	37,713	1,036	83	19.72	325,202
2016	400	115	1,650	200	999,848	1,538,465	22,541	6,270	28,261	163,015	57,072	0.278	642,870	111,912	754,782	586,557	81%	0	0	81,264	98,700	244	27	18	198	2,174	37,481	1,033	81	19.72	325,948
2018	400	115	1,500	200	1,128,245	1,682,153	21,701	6,232	30,760	178,240	58,692	0.304	642,870	120,958	763,828	586,557	79%	0	0	90,398	106,860	264	29	20	215	2,354	40,580	1,124	101	17.93	325,047
2020	400	115	1,650	200	1,051,824	1,556,830	17,912	6,325	29,274	164,961	53,510	0.281	642,870	108,950	751,820	586,557	81%	4	0	77,855	97,211	240	27	18	195	2,141	36,916	1,052	82	19.72	327,910
2022	400	115	1,650	200	960,660	1,462,964	16,183	6,365	30,676	155,015	53,224	0.264	642,870	108,611	751,481	586,557	81%	4	0	77,403	97,327	240	27	18	195	2,144	36,960	1,066	83	19.72	328,329
2024	400	115	1,650	200	883,770	1,381,074	14,580	6,368	31,746	146,338	52,694	0.249	642,870	108,565	751,435	586,557	81%	4	0	77,337	97,321	240	27	18	195	2,144	36,957	1,067	83	19.72	328,404
2026	400	115	1,650	200	830,011	1,323,902	13,221	6,368	32,744	140,280	52,332	0.239	642,870	108,565	751,435	586,557	81%	4	0	77,337	97,321	240	27	18	195	2,144	36,957	1,067	83	19.72	328,404
2028	400	115	1,650	200	794,934	1,287,607	12,168	6,368	33,668	136,434	52,203	0.233	642,870	108,565	751,435	586,557	81%	4	0	77,337	97,321	240	27	18	195	2,144	36,957	1,067	83	19.72	328,404
2030	450	115	1,650	200	817,172	1,251,667	10,809	5,896	29,334	132,626	46,039	0.226	723,228	92,263	815,491	586,557	84%	0	0	141,410	82,616	204	23	15	166	1,820	31,373	903	69	19.72	328,178
2032	450	115	1,650	200	810,193	1,249,827	10,538	5,896	30,150	132,431	46,583	0.226	723,228	92,263	815,491	586,557	84%	0	0	141,410	82,616	204	23	15	166	1,820	31,373	903	69	19.72	328,178
2034	450	115	1,650	200	800,644	1,249,381	10,341	5,896	31,310	132,384	47,548	0.226	723,228	92,263	815,491	586,557	84%	0	0	141,410	82,616	204	23	15	166	1,820	31,373	903	69	19.72	328,178
2036	450	115	1,650	200	792,085	1,246,146	10,184	5,896	32,032	132,041	48,112	0.225	723,228	92,263	815,491	586,557	84%	0	0	141,410	82,616	204	23	15	166	1,820	31,373	903	69	19.72	328,178
2038	450	115	1,650	200	788,537	1,248,101	10,045	5,896	32,754	132,248	48,695	0.225	723,228	92,263	815,491	586,557	84%	0	0	141,410	82,616	204	23	15	166	1,820	31,373	903	69	19.72	328,178
2040	450	115	1,650	200	780,704	1,250,301	9,916	5,896	33,946	132,481	49,758	0.226	723,228	92,263	815,491	586,557	84%	0	0	141,410	82,616	204	23	15	166	1,820	31,373	903	69	19.72	328,178
2042	450	115	1,650	200	777,140	1,236,248	9,777	5,896	32,973	130,992	48,647	0.223	723,228	92,263	815,491	586,557	84%	0	0	141,410	82,616	204	23	15	166	1,820	31,373	903	69	19.72	328,178
2044	450	115	1,800	200	787,100	1,231,967	10,116	6,004	31,018	130,539	47,138	0.223	723,228	85,409	808,636	586,557	85%	15	0	133,520	76,480	189	21	14	154	1,685	29,043	836	60	21.51	331,903
2046	450	115	1,800	200	783,448	1,231,923	9,974	6,004	31,541	130,534	47,518	0.223	723,228	85,409	808,636	586,557	85%	15	0	133,520	76,480	189	21	14	154	1,685	29,043	836	60	21.51	331,903
2048	450	115	1,800	200	775,418	1,227,074	9,790	6,004	32,064	130,020	47,857	0.222	723,228	85,409	808,636	586,557	85%	15	0	133,520	76,480	189	21	14	154	1,685	29,043	836	60	21.51	331,903
2050	450	115	1,800	200	771,998	1,227,056	9,657	6,004	32,557	130,018	48,218	0.222	723,228	85,409	808,636	586,557	85%	15	0	133,520	76,480	189	21	14	154	1,685	29,043	836	60	21.51	331,903
Sunshot	500	115	2,050	200	608,439	885,409	6,711	5,888	16,749	93,817	29,348	0.16	803,588	61,594	865,181	586,557	89%	0	0	188,937	55,618	137	15	10	112	1,225	21,121	622	44	24.5	338,697

Accelerated Technology Improvement - Los Angeles Commercial (with Genset)

Battery Projection Study	PV	Diesel Genset	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Annual Cost	Operating Cost	COE	PV Production	Genset Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Emissions CO2	CO	UHC	PM	SO2	NOx	Genset Fuel	Genset Hours	Genset Starts	Battery Autonomy	Battery Throughput
	kW	kW	Quantity	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	L/yr	hr/yr	starts/yr	hr	kWh/yr
Bloomberg New Energy Finance	600	115	1,650	250	923,758	1,516,999	18,532	4,959	16,106	101,255	39,597	0.173	964,304	60,007	1,024,311	586,557	0.9	0	0	350,923	53,483	132	15	10	107	1,178	20,310	577	45	19.72	326,966
Deutsche Bank	600	115	1,650	200	778,881	1,278,891	12,022	5,028	16,324	85,362	33,374	0.146	964,304	60,224	1,024,528	586,557	0.9	0	0	351,267	54,207	134	15	10	109	1,194	20,585	601	45	19.72	326,494
McKinsey	600	115	1,750	250	745,093	1,195,064	10,324	5,015	14,695	79,766	30,034	0.136	964,304	54,731	1,019,035	586,557	0.91	1	0	344,837	48,799	120	13	9	98	1,075	18,531	527	41	20.91	330,468
Department of Energy	600	115	2,100	250	692,197	1,048,179	7,640	5,339	10,782	69,962	23,761	0.119	964,304	39,813	1,004,117	586,557	0.93	0	0	327,915	35,804	88	10	7	72	789	13,597	396	30	25.1	338,577
Battery OEM	600	115	2,100	250	660,487	994,913	6,201	5,339	10,782	66,407	22,322	0.113	964,304	39,813	1,004,117	586,557	0.93	0	0	327,915	35,804	88	10	7	72	789	13,597	396	30	25.1	338,577

Demand-side Improvement - Los Angeles Commercial (with Genset)

Year	PV	Diesel Genset	1kWh Li-ion	Converter	Efficiency Case	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Annual Cost	Operating Cost	COE	PV Production	Genset Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Emissions CO2	CO	UHC	PM	SO2	NOx	Genset Fuel	Genset Hours	Genset Starts	Battery Autonomy	Battery Throughput
	kW	kW	Quantity	kW		$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	L/yr	hr/yr	starts/yr	hr	kWh/yr
2014	300	115	1,050	150	Yes	838,398	1,295,128	24,131	3,839	20,424	137,231	48,395	0.354	482,152	67,315	549,467	387,127	83%	0	0	103,259	58,973	146	16	11	118	1,299	22,395	605	72	12.55	220,848
2016	300	115	1,050	150	Yes	726,165	1,149,613	21,321	3,842	16,903	114,205	42,066	0.295	482,152	67,369	549,521	387,127	83%	0	0	103,325	59,033	146	16	11	119	1,300	22,417	606	72	12.55	220,805
2018	300	115	1,050	150	Yes	846,129	1,440,757	20,934	3,842	16,992	101,203	41,768	0.261	482,152	67,369	549,521	387,127	83%	0	0	103,325	59,033	146	16	11	119	1,300	22,417	606	72	12.55	220,805
2020	300	115	1,050	150	Yes	764,695	1,381,950	19,384	3,897	17,919	92,241	41,200	0.238	482,152	67,384	549,536	387,127	83%	0	0	103,323	59,502	147	16	11	119	1,311	22,596	625	72	12.55	220,868
2022	300	115	1,050	150	Yes	701,227	1,310,113	17,931	3,908	18,801	87,446	40,641	0.226	482,152	67,461	549,613	387,127	83%	0	0	103,407	59,650	147	16	11	120	1,314	22,652	629	72	12.55	220,842
2024	300	115	1,050	150	Yes	647,979	1,246,288	16,609	3,914	19,412	83,185	39,935	0.215	482,152	67,172	549,324	387,127	83%	0	0	103,122	59,509	147	16	11	120	1,311	22,598	631	71	12.55	220,827
2026	350	115	1,150	150	Yes	687,133	1,199,338	14,968	3,706	15,514	80,052	34,188	0.207	562,510	52,044	614,554	387,127	87%	0	0	168,379	46,109	114	13	9	93	1,016	17,510	489	51	13.74	221,184
2028	350	115	1,150	150	Yes	661,261	1,166,655	14,113	3,706	15,915	77,870	33,733	0.201	562,510	51,883	614,393	387,127	87%	0	0	168,207	46,003	114	13	9	92	1,013	17,470	489	51	13.74	221,226
2030	350	115	1,150	150	Yes	635,139	1,136,609	13,431	3,706	16,334	75,865	33,471	0.196	562,510	51,883	614,393	387,127	87%	0	0	168,207	46,003	114	13	9	92	1,013	17,470	489	51	13.74	221,226
2032	350	115	1,300	150	Yes	650,292	1,134,386	13,985	3,831	14,496	75,716	32,312	0.196	562,510	44,585	607,095	387,127	88%	0	0	160,609	39,721	98	11	7	80	875	15,084	428	42	15.54	223,831
2034	350	115	1,300	150	Yes	642,814	1,132,569	13,805	3,831	15,054	75,595	32,689	0.195	562,510	44,585	607,095	387,127	88%	0	0	160,609	39,721	98	11	7	80	875	15,084	428	42	15.54	223,831
2036	350	115	1,300	150	Yes	636,116	1,128,902	13,661	3,831	15,401	75,350	32,892	0.195	562,510	44,585	607,095	387,127	88%	0	0	160,609	39,721	98	11	7	80	875	15,084	428	42	15.54	223,831
2038	350	115	1,300	150	Yes	633,321	1,129,399	13,533	3,831	15,748	75,384	33,112	0.195	562,510	44,585	607,095	387,127	88%	0	0	160,609	39,721	98	11	7	80	875	15,084	428	42	15.54	223,831
2040	400	115	1,400	150	Yes	694,571	1,129,005	13,721	3,694	11,582	75,357	28,997	0.195	642,870	31,373	674,243	387,127	92%	0	0	227,801	28,188	70	8	5	57	621	10,705	311	30	16.73	223,944
2042	350	115	1,300	150	Yes	624,387	1,118,359	13,287	3,831	15,853	74,647	32,971	0.193	562,510	44,585	607,095	387,127	88%	0	0	160,609	39,721	98	11	7	80	875	15,084	428	42	15.54	223,831
2044	400	115	1,400	150	Yes	684,607	1,112,749	13,450	3,694	11,432	74,272	28,577	0.192	642,870	31,373	674,243	387,127	92%	0	0	227,801	28,188	70	8	5	57	621	10,705	311	30	16.73	223,944
2046	400	115	1,400	150	Yes	681,779	1,110,876	13,322	3,694	11,625	74,147	28,641	0.192	642,870	31,373	674,243	387,127	92%	0	0	227,801	28,188	70	8	5	57	621	10,705	311	30	16.73	223,944
2048	400	115	1,400	150	Yes	675,021	1,104,527	13,156	3,694	11,818	73,723	28,668	0.19	642,870	31,373	674,243	387,127	92%	0	0	227,801	28,188	70	8	5	57	621	10,705	311	30	16.73	223,944
2050	400	115	1,600	150	Yes	695,083	1,101,555	13,926	3,910	9,295	73,525	27,131	0.19	642,870	24,077	666,946	387,127	94%	0	0	219,691	21,834	54	6	4	44	481	8,292	247	23	19.12	226,957
Sunshot	400	115	1,600	150	Yes	500,235	820,950	10,921	3,910	6,575	54,796	21,407	0.142	642,870	24,077	666,946	387,127	94%	0	0	219,691	21,834	54	6	4	44	481	8,292	247	23	19.12	226,957

Combined Improvement - Los Angeles Commercial (with Genset)

Battery Projection Study	PV	Diesel Genset	1kWh Li-ion	Converter	Efficiency Case	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Annual Cost	Operating Cost	COE	PV Production	Genset Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Emissions CO2	CO	UHC	PM	SO2	NOx	Genset Fuel	Genset Hours	Genset Starts	Battery Autonomy	Battery Throughput
	kW	kW	Quantity	kW		$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	L/yr	hr/yr	starts/yr	hr	kWh/yr
Bloomberg New Energy Finance	400	115	1,100	150	Yes	639,479	1,133,138	17,620	3,419	11,911	75,633	32,950	0.195	642,870	44,477	687,347	387,127	0.89	0	0	242,098	39,553	98	11	7	79	871	15,020	424	47	13.15	218,417
Deutsche Bank	400	115	1,100	150	Yes	545,561	977,116	13,376	3,436	11,993	65,219	28,805	0.168	642,870	44,670	687,540	387,127	0.88	0	0	242,302	39,825	98	11	7	80	877	15,124	430	47	13.15	218,378
McKinsey	400	115	1,100	150	Yes	512,308	922,047	11,870	3,439	12,039	61,544	27,349	0.159	642,870	44,866	687,736	387,127	0.88	0	0	242,512	39,978	99	11	7	80	881	15,182	431	47	13.15	218,325
Department of Energy	400	115	1,600	150	Yes	500,219	820,934	10,921	3,910	6,575	54,795	21,407	0.142	642,870	24,077	666,946	387,127	0.94	0	0	219,691	21,834	54	6	4	44	481	8,292	247	23	19.12	226,957
Battery OEM	400	115	1,600	150	Yes	476,059	780,350	9,825	3,910	6,575	52,086	20,310	0.135	642,870	24,077	666,946	387,127	0.94	0	0	219,691	21,834	54	6	4	44	481	8,292	247	23	19.12	226,957

COMMERCIAL TABLES - HONOLULU

Base Case - Honolulu Commercial (with Genset)

Year	PV	Diesel Genset	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Annual Cost	Operating Cost	COE	PV Production	Genset Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Emissions CO2	CO	UHC	PM	SO2	NOx	Genset Fuel	Genset Hours	Genset Starts	Battery Autonomy	Battery Throughput
	kW	kW	Quantity	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	L/yr	hr/yr	starts/yr	hr	kWh/yr
2014	500	150	1,950	200	1,416,740	2,187,644	32,005	7,650	42,030	231,801	81,685	0.321	798,791	136,340	935,131	722,700	81%	0	0	107,969	121,357	300	33	23	244	2,673	46,085	1,000	88	18.91	391,066
2016	500	150	1,950	250	1,226,593	1,921,887	27,947	7,429	33,696	190,925	69,072	0.264	798,791	133,591	932,382	722,700	82%	0	0	104,500	117,683	290	32	22	236	2,592	44,690	941	84	18.91	393,545
2018	550	150	1,950	200	1,504,169	2,403,060	26,848	7,061	29,232	168,798	63,141	0.234	878,669	113,792	992,461	722,700	84%	0	0	164,542	101,552	251	28	19	204	2,237	38,564	843	74	18.91	393,830
2020	550	150	1,950	200	1,354,792	2,284,343	24,365	7,166	30,513	152,472	62,044	0.211	878,669	112,103	990,772	722,700	84%	0	0	162,639	101,325	250	28	19	203	2,232	38,478	871	73	18.91	394,939
2022	600	150	1,950	250	1,312,280	2,144,251	21,174	6,671	27,686	143,121	55,531	0.198	958,549	97,955	1,056,504	722,700	86%	0	0	229,142	87,839	217	24	16	176	1,935	33,357	739	60	18.91	391,482
2024	650	150	2,000	250	1,280,660	2,011,529	18,555	6,321	23,907	134,263	48,783	0.186	1,038,429	81,612	1,120,040	722,700	89%	0	0	292,786	73,288	181	20	14	147	1,614	27,831	619	51	19.4	394,032
2026	650	150	2,200	250	1,240,514	1,920,512	17,847	6,410	21,131	128,188	45,388	0.177	1,038,429	69,672	1,108,101	722,700	90%	0	0	279,324	62,805	155	17	12	126	1,383	23,850	536	43	21.34	399,672
2028	650	150	2,200	250	1,191,412	1,855,818	16,210	6,410	21,727	123,870	44,347	0.171	1,038,429	69,672	1,108,101	722,700	90%	0	0	279,324	62,805	155	17	12	126	1,383	23,850	536	43	21.34	399,672
2030	650	150	2,200	250	1,142,396	1,796,005	14,916	6,410	22,300	119,877	43,626	0.166	1,038,429	69,672	1,108,101	722,700	90%	0	0	279,324	62,805	155	17	12	126	1,383	23,850	536	43	21.34	399,672
2032	650	150	2,200	250	1,133,090	1,789,675	14,495	6,410	22,920	119,455	43,825	0.165	1,038,429	69,672	1,108,101	722,700	90%	0	0	279,324	62,805	155	17	12	126	1,383	23,850	536	43	21.34	399,672
2034	650	150	2,200	250	1,119,858	1,785,093	14,190	6,410	23,802	119,149	44,402	0.165	1,038,429	69,672	1,108,101	722,700	90%	0	0	279,324	62,805	155	17	12	126	1,383	23,850	536	43	21.34	399,672
2036	650	150	2,200	250	1,107,946	1,777,732	13,945	6,410	24,351	118,658	44,706	0.164	1,038,429	69,672	1,108,101	722,700	90%	0	0	279,324	62,805	155	17	12	126	1,383	23,850	536	43	21.34	399,672
2038	650	150	2,200	250	1,103,216	1,777,996	13,730	6,410	24,899	118,675	45,039	0.164	1,038,429	69,672	1,108,101	722,700	90%	0	0	279,324	62,805	155	17	12	126	1,383	23,850	536	43	21.34	399,672
2040	700	150	2,350	300	1,171,836	1,777,217	14,278	6,226	19,903	118,623	40,407	0.164	1,118,308	54,043	1,172,351	722,700	93%	0	0	342,658	48,439	120	13	9	97	1,067	18,395	407	33	22.79	402,103
2042	650	150	2,200	250	1,087,520	1,758,559	13,313	6,410	25,066	117,378	44,790	0.162	1,038,429	69,672	1,108,101	722,700	90%	0	0	279,324	62,805	155	17	12	126	1,383	23,850	536	43	21.34	399,672
2044	700	150	2,350	300	1,154,825	1,749,555	13,824	6,226	19,646	116,777	39,696	0.162	1,118,308	54,043	1,172,351	722,700	93%	0	0	342,658	48,439	120	13	9	97	1,067	18,395	407	33	22.79	402,103
2046	700	150	2,350	300	1,150,078	1,746,526	13,608	6,226	19,977	116,575	39,811	0.161	1,118,308	54,043	1,172,351	722,700	93%	0	0	342,658	48,439	120	13	9	97	1,067	18,395	407	33	22.79	402,103
2048	700	150	2,350	300	1,138,449	1,735,499	13,317	6,226	20,308	115,839	39,851	0.16	1,118,308	54,043	1,172,351	722,700	93%	0	0	342,658	48,439	120	13	9	97	1,067	18,395	407	33	22.79	402,103
2050	700	150	2,350	300	1,133,984	1,732,680	13,114	6,226	20,620	115,651	39,961	0.16	1,118,308	54,043	1,172,351	722,700	93%	0	0	342,658	48,439	120	13	9	97	1,067	18,395	407	33	22.79	402,103
Sunshot	700	150	2,350	300	808,613	1,248,842	8,571	6,226	14,587	83,356	29,384	0.115	1,118,308	54,043	1,172,351	722,700	93%	0	0	342,658	48,439	120	13	9	97	1,067	18,395	407	33	22.79	402,103

Base Case - Honolulu Commercial (without Genset)

Year	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Annual Cost	Operating Cost	COE	PV Production	Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Emissions CO2	CO	UHC	PM	SO2	NOx	Battery Autonomy	Battery Throughput
	kW	Quantity	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	hr	kWh/yr
2014	1,000	3,900	300	2,667,479	3,300,708	59,297	7,800	0	349,741	67,097	0.484	1,597,581	1,597,581	722,103	100%	718	596	767,193	0	0	0	0	0	0	37.83	404,299
2016	1,000	3,900	300	2,275,185	2,859,423	50,240	7,800	0	284,062	58,039	0.393	1,597,581	1,597,581	722,103	100%	718	596	767,193	0	0	0	0	0	0	37.83	404,299
2018	1,000	3,900	300	2,683,337	3,496,461	49,316	7,800	0	245,602	57,116	0.34	1,597,581	1,597,581	722,103	100%	718	596	767,193	0	0	0	0	0	0	37.83	404,299
2020	1,000	3,900	300	2,400,584	3,175,959	43,954	7,800	0	211,985	51,754	0.294	1,597,581	1,597,581	722,103	100%	718	596	767,193	0	0	0	0	0	0	37.83	404,299
2022	1,000	3,900	300	2,182,560	2,886,182	39,164	7,800	0	192,643	46,964	0.267	1,597,581	1,597,581	722,103	100%	718	596	767,193	0	0	0	0	0	0	37.83	404,299
2024	1,000	3,900	300	1,997,637	2,636,392	34,835	7,800	0	175,970	42,635	0.244	1,597,581	1,597,581	722,103	100%	718	596	767,193	0	0	0	0	0	0	37.83	404,299
2026	1,000	3,900	300	1,867,843	2,451,177	31,136	7,800	0	163,608	38,936	0.227	1,597,581	1,597,581	722,103	100%	718	596	767,193	0	0	0	0	0	0	37.83	404,299
2028	900	4,300	300	1,727,828	2,320,403	30,952	8,600	0	154,879	39,552	0.214	1,437,823	1,437,823	722,149	100%	670	550	606,501	0	0	0	0	0	0	41.71	408,357
2030	900	4,300	300	1,645,024	2,200,508	28,477	8,600	0	146,876	37,077	0.203	1,437,823	1,437,823	722,149	100%	670	550	606,501	0	0	0	0	0	0	41.71	408,357
2032	900	4,300	300	1,626,835	2,169,978	27,653	8,600	0	144,839	36,253	0.201	1,437,823	1,437,823	722,149	100%	670	550	606,501	0	0	0	0	0	0	41.71	408,357
2034	900	4,300	300	1,604,677	2,138,886	27,057	8,600	0	142,763	35,657	0.198	1,437,823	1,437,823	722,149	100%	670	550	606,501	0	0	0	0	0	0	41.71	408,357
2036	900	4,300	300	1,585,099	2,112,140	26,578	8,600	0	140,978	35,178	0.195	1,437,823	1,437,823	722,149	100%	670	550	606,501	0	0	0	0	0	0	41.71	408,357
2038	900	4,300	300	1,575,854	2,096,592	26,157	8,600	0	139,940	34,757	0.194	1,437,823	1,437,823	722,149	100%	670	550	606,501	0	0	0	0	0	0	41.71	408,357
2040	900	4,300	300	1,558,168	2,073,026	25,765	8,600	0	138,367	34,365	0.192	1,437,823	1,437,823	722,149	100%	670	550	606,501	0	0	0	0	0	0	41.71	408,357
2042	900	4,300	300	1,548,880	2,057,418	25,343	8,600	0	137,326	33,943	0.19	1,437,823	1,437,823	722,149	100%	670	550	606,501	0	0	0	0	0	0	41.71	408,357
2044	900	4,300	300	1,530,850	2,033,279	24,935	8,600	0	135,714	33,535	0.188	1,437,823	1,437,823	722,149	100%	670	550	606,501	0	0	0	0	0	0	41.71	408,357
2046	900	4,300	300	1,522,164	2,018,660	24,539	8,600	0	134,739	33,139	0.187	1,437,823	1,437,823	722,149	100%	670	550	606,501	0	0	0	0	0	0	41.71	408,357
2048	900	4,300	300	1,504,693	1,994,237	24,075	8,600	0	133,109	32,675	0.184	1,437,823	1,437,823	722,149	100%	670	550	606,501	0	0	0	0	0	0	41.71	408,357
2050	900	4,300	300	1,496,523	1,980,506	23,704	8,600	0	132,192	32,304	0.183	1,437,823	1,437,823	722,149	100%	670	550	606,501	0	0	0	0	0	0	41.71	408,357
Sunshot	900	4,300	300	1,032,994	1,398,549	15,800	8,600	0	93,348	24,400	0.129	1,437,823	1,437,823	722,149	100%	670	550	606,501	0	0	0	0	0	0	41.71	408,357

Accelerated Technology Improvement - Honolulu Commercial (with Genset)

Battery Projection Study	PV	Diesel Genset	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Annual Cost	Operating Cost	COE	PV Production	Genset Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Emissions CO2	CO	UHC	PM	SO2	NOx	Genset Fuel	Genset Hours	Genset Starts	Battery Autonomy	Battery Throughput
	kW	kW	Quantity	kW	$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	L/yr	hr/yr	starts/yr	hr	kWh/yr
Bloomberg New Energy Finance	800	150	1,950	250	1,164,214	1,804,162	21,602	5,588	15,525	120,422	42,714	0.167	1,278,062	56,709	1,334,771	722,700	92%	0	0	507,561	51,553	127	14	10	104	1,135	19,577	450	39	18.91	391,945
Deutsche Bank	750	150	2,050	250	974,837	1,519,930	14,541	5,829	16,013	101,450	36,383	0.14	1,198,187	58,645	1,256,833	722,700	92%	0	0	428,648	53,176	131	15	10	107	1,171	20,193	461	40	19.88	395,974
McKinsey	750	150	2,050	250	912,866	1,415,873	11,732	5,829	16,013	94,505	33,574	0.131	1,198,187	58,645	1,256,833	722,700	92%	0	0	428,648	53,176	131	15	10	107	1,171	20,193	461	40	19.88	395,974
Department of Energy	700	150	2,350	300	808,590	1,248,819	8,571	6,226	14,587	83,354	29,384	0.115	1,118,308	54,043	1,172,351	722,700	93%	0	0	342,658	48,439	120	13	9	97	1,067	18,395	407	33	22.79	402,103
Battery OEM	750	150	2,750	300	835,293	1,184,619	7,644	6,483	9,189	79,069	23,316	0.109	1,198,187	33,777	1,231,964	722,700	95%	0	0	400,630	30,516	75	8	6	61	672	11,588	262	21	26.67	407,643

Demand-side Improvement - Honolulu Commercial (with Genset)

Year	PV	Diesel Genset	1kWh Li-ion	Converter	Efficiency Case	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Annual Cost	Operating Cost	COE	PV Production	Genset Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Emissions CO2	CO	UHC	PM	SO2	NOx	Genset Fuel	Genset Hours	Genset Starts	Battery Autonomy	Battery Throughput
	kW	kW	Quantity	kW		$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	L/yr	hr/yr	starts/yr	hr	kWh/yr
2014	350	150	1,200	150	Yes	975,190	1,573,024	30,568	4,894	27,884	166,677	63,346	0.349	559,154	90,379	649,533	476,981	81%	0	0	101,094	80,513	199	22	15	162	1,773	30,575	665	94	11.64	266,791
2016	350	150	1,200	150	Yes	846,138	1,398,879	26,979	4,894	23,038	138,968	54,911	0.291	559,154	90,296	649,450	476,981	81%	0	0	101,008	80,459	199	22	15	162	1,772	30,554	665	94	11.64	266,802
2018	400	150	1,300	150	Yes	1,090,437	1,746,018	24,100	4,483	17,468	122,646	46,050	0.257	639,031	68,082	707,113	476,981	86%	0	0	159,493	60,684	150	17	11	122	1,337	23,044	502	64	12.61	264,037
2020	400	150	1,300	150	Yes	985,686	1,662,751	22,244	4,550	18,397	110,983	45,192	0.233	639,031	67,839	706,870	476,981	86%	0	0	159,236	61,093	151	17	11	123	1,346	23,200	520	63	12.61	263,981
2022	400	150	1,350	200	Yes	922,198	1,567,486	20,789	4,429	17,853	104,624	43,071	0.219	639,031	63,911	702,942	476,981	87%	0	0	155,623	56,642	140	15	11	114	1,248	21,510	461	54	13.09	264,780
2024	400	150	1,350	200	Yes	852,378	1,483,768	19,238	4,429	18,477	99,037	42,143	0.208	639,031	63,911	702,942	476,981	87%	0	0	155,623	56,642	140	15	11	114	1,248	21,510	461	54	13.09	264,780
2026	400	150	1,350	200	Yes	804,757	1,425,269	17,931	4,429	19,058	95,132	41,417	0.199	639,031	63,911	702,942	476,981	87%	0	0	155,623	56,642	140	15	11	114	1,248	21,510	461	54	13.09	264,780
2028	450	150	1,350	150	Yes	826,104	1,386,145	16,488	4,230	16,663	92,520	37,381	0.194	718,912	53,580	772,491	476,981	89%	0	0	225,366	48,166	119	13	9	97	1,061	18,291	408	47	13.09	263,848
2030	450	150	1,350	150	Yes	794,526	1,349,270	15,695	4,230	17,102	90,059	37,027	0.189	718,912	53,580	772,491	476,981	89%	0	0	225,366	48,166	119	13	9	97	1,061	18,291	408	47	13.09	263,848
2032	450	150	1,350	150	Yes	788,815	1,346,810	15,437	4,230	17,578	89,895	37,244	0.188	718,912	53,580	772,491	476,981	89%	0	0	225,366	48,166	119	13	9	97	1,061	18,291	408	47	13.09	263,848
2034	450	150	1,350	150	Yes	780,184	1,345,513	15,249	4,230	18,254	89,808	37,734	0.188	718,912	53,580	772,491	476,981	89%	0	0	225,366	48,166	119	13	9	97	1,061	18,291	408	47	13.09	263,848
2036	450	150	1,350	150	Yes	772,363	1,341,745	15,099	4,230	18,675	89,557	38,004	0.188	718,912	53,580	772,491	476,981	89%	0	0	225,366	48,166	119	13	9	97	1,061	18,291	408	47	13.09	263,848
2038	450	150	1,350	150	Yes	769,461	1,343,166	14,967	4,230	19,096	89,652	38,293	0.188	718,912	53,580	772,491	476,981	89%	0	0	225,366	48,166	119	13	9	97	1,061	18,291	408	47	13.09	263,848
2040	450	150	1,350	150	Yes	762,234	1,344,507	14,844	4,230	19,791	89,741	38,865	0.188	718,912	53,580	772,491	476,981	89%	0	0	225,366	48,166	119	13	9	97	1,061	18,291	408	47	13.09	263,848
2042	450	150	1,350	150	Yes	759,318	1,331,111	14,711	4,230	19,224	88,847	38,165	0.186	718,912	53,580	772,491	476,981	89%	0	0	225,366	48,166	119	13	9	97	1,061	18,291	408	47	13.09	263,848
2044	450	150	1,950	200	Yes	829,683	1,324,557	17,579	4,733	10,720	88,410	33,031	0.185	718,912	29,494	748,406	476,981	94%	0	0	198,913	26,432	65	7	5	53	582	10,038	222	22	18.91	272,616
2046	450	150	1,950	200	Yes	825,744	1,320,635	17,399	4,733	10,901	88,148	33,032	0.185	718,912	29,494	748,406	476,981	94%	0	0	198,913	26,432	65	7	5	53	582	10,038	222	22	18.91	272,616
2048	450	150	1,950	200	Yes	817,402	1,311,585	17,171	4,733	11,081	87,544	32,985	0.184	718,912	29,494	748,406	476,981	94%	0	0	198,913	26,432	65	7	5	53	582	10,038	222	22	18.91	272,616
2050	450	150	1,950	200	Yes	813,697	1,307,915	17,003	4,733	11,252	87,299	32,987	0.183	718,912	29,494	748,406	476,981	94%	0	0	198,913	26,432	65	7	5	53	582	10,038	222	22	18.91	272,616
Sunshot	450	150	1,950	200	Yes	587,539	977,149	13,313	4,733	7,960	65,221	26,005	0.137	718,912	29,494	748,406	476,981	94%	0	0	198,913	26,432	65	7	5	53	582	10,038	222	22	18.91	272,616

Combined Improvement - Honolulu Commercial (with Genset)

Battery Projection Study	PV	Diesel Genset	1kWh Li-ion	Converter	Efficiency Case	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Fuel Cost	Total Annual Cost	Operating Cost	COE	PV Production	Genset Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Emissions CO2	CO	UHC	PM	SO2	NOx	Genset Fuel	Genset Hours	Genset Starts	Battery Autonomy	Battery Throughput
	kW	kW	Quantity	kW		$	$	$/yr	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	L/yr	hr/yr	starts/yr	hr	kWh/yr
Bloomberg New Energy Finance	500	150	1,250	150	Yes	769,808	1,346,759	21,628	3,858	13,024	89,892	38,510	0.188	798,791	48,317	847,108	476,981	0.9	0	0	300,389	43,248	107	12	8	87	953	16,423	362	45	12.12	261,737
Deutsche Bank	500	150	1,250	150	Yes	663,083	1,160,587	16,300	3,865	13,042	77,465	33,207	0.162	798,791	48,312	847,102	476,981	0.9	0	0	300,384	43,308	107	12	8	87	954	16,446	364	45	12.12	261,736
McKinsey	500	150	1,250	150	Yes	625,295	1,094,508	14,412	3,865	13,042	73,055	31,318	0.153	798,791	48,312	847,102	476,981	0.9	0	0	300,384	43,308	107	12	8	87	954	16,446	364	45	12.12	261,736
Department of Energy	450	150	1,950	200	Yes	587,519	977,130	13,313	4,733	7,960	65,220	26,005	0.137	718,912	29,494	748,406	476,981	0.94	0	0	198,913	26,432	65	7	5	53	582	10,038	222	22	18.91	272,616
Battery OEM	450	150	1,950	200	Yes	558,074	927,668	11,977	4,733	7,960	61,919	24,669	0.13	718,912	29,494	748,406	476,981	0.94	0	0	198,913	26,432	65	7	5	53	582	10,038	222	22	18.91	272,616

COMMERCIAL TABLES - ALL LOCATIONS

Commercial (All Scenario and Geography) Financial Costs								
Year	Diesel Price	PV Capital Cost	PV Replacement Cost	Li-ion Battery Capital Cost	Li-ion Battery Replacement Cost	Inverter Capital Cost	Inverter Replacement Cost	Interest Rate
	$/L	$/Wdc	$/Wdc	$/kWh	$/kWh	$	$	%
2014	0.912	1.49	3.18	289.61	619.88	0.16	0.35	9.5
2016	0.754	1.32	2.85	234.15	506.05	0.14	0.31	8.7
2018	0.758	1.58	2.6	269.83	443.47	0.17	0.28	4.9
2020	0.793	1.43	2.37	236.56	391.23	0.16	0.26	4.4
2022	0.83	1.32	2.19	210.4	347.96	0.14	0.24	4.4
2024	0.859	1.23	2.03	186.83	308.99	0.13	0.22	4.4
2026	0.886	1.18	1.95	166.37	275.15	0.13	0.21	4.4
2028	0.911	1.16	1.91	149.96	248	0.13	0.21	4.4
2030	0.935	1.13	1.88	137.68	227.69	0.12	0.2	4.4
2032	0.961	1.13	1.86	133.45	220.7	0.12	0.2	4.4
2034	0.998	1.12	1.85	130.39	215.64	0.12	0.2	4.4
2036	1.021	1.11	1.84	127.93	211.58	0.12	0.2	4.4
2038	1.044	1.11	1.83	125.78	208.01	0.12	0.2	4.4
2040	1.082	1.1	1.82	123.76	204.68	0.12	0.2	4.4
2042	1.051	1.1	1.82	121.6	201.1	0.12	0.2	4.4
2044	1.068	1.09	1.81	119.5	197.64	0.12	0.2	4.4
2046	1.086	1.09	1.8	117.48	194.28	0.12	0.2	4.4
2048	1.104	1.08	1.79	115.51	191.04	0.12	0.19	4.4
2050	1.121	1.08	1.78	113.61	187.89	0.12	0.19	4.4
Sunshot	0.793	0.76	1.25	75.58	125	0.08	0.13	4.4

Commercial (Accelerated Technology and Combine Improvement Scenario) All Geography Financial Costs						
Battery Projection Study	PV Capital Cost	PV Replacement Cost	Li-ion Battery Capital Cost	Li-ion Battery Replacement Cost	Inverter Capital Cost	Inverter Replacement Cost
	$/Wdc	$/Wdc	$/kWh	$/kWh	$	$
Bloomberg New Energy Finance	0.76	1.25	236.52	391.23	0.08	0.13
Deutsche Bank	0.76	1.25	151.14	250	0.08	0.13
McKinsey	0.76	1.25	120.91	200	0.08	0.13
Department of Energy	0.76	1.25	75.57	125	0.08	0.13
Battery OEM	0.76	1.25	60.47	100	0.08	0.13

Diesel Prices[30]		
1 gallon = 3.78541 liters		
	[2012$/gallon]	[2012$/liter]
2012	$3.70	$0.98
2013	$3.66	$0.97
2014	$3.45	$0.91
2015	$2.93	$0.77
2016	$2.85	$0.75
2017	$2.84	$0.75
2018	$2.87	$0.76
2019	$2.94	$0.78
2020	$3.00	$0.79
2021	$3.07	$0.81
2022	$3.14	$0.83
2023	$3.20	$0.84
2024	$3.25	$0.86
2025	$3.31	$0.87
2026	$3.35	$0.89
2027	$3.41	$0.90
2028	$3.45	$0.91
2029	$3.50	$0.92
2030	$3.54	$0.93
2031	$3.58	$0.95
2032	$3.64	$0.96
2033	$3.69	$0.97
2034	$3.78	$1.00
2035	$3.82	$1.01
2036	$3.86	$1.02
2037	$3.91	$1.03
2038	$3.95	$1.04
2039	$4.02	$1.06
2040	$4.10	$1.08
2041	$3.94	$1.04
2042	$3.98	$1.05
2043	$4.01	$1.06
2044	$4.04	$1.07
2045	$4.08	$1.08
2046	$4.11	$1.09
2047	$4.14	$1.09
2048	$4.18	$1.10
2049	$4.21	$1.11
2050	$4.24	$1.12
SunShot	$3.00	$0.79

RESIDENTIAL TABLES - WESTCHESTER, NY

Base Case - Westchester Residential (100% Load Met)

Year	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Battery Autonomy	Battery Throughput
	kW		kW	$	$	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	hr	kWh/yr
2014	20	240	9	157,544	198,300	3,602	480	19,862	4,082	1.665	25,959	25,959	11,927	100%	10	9	12,135	140.95	7,380
2016	20	240	9	132,018	170,406	3,055	480	15,692	3,535	1.316	25,959	25,959	11,927	100%	10	9	12,135	140.95	7,380
2018	20	240	9	167,036	215,075	2,894	480	15,108	3,374	1.267	25,959	25,959	11,927	100%	10	9	12,135	140.95	7,380
2020	20	240	9	148,898	193,603	2,566	480	13,191	3,046	1.106	25,959	25,959	11,927	100%	10	9	12,135	140.95	7,380
2022	20	240	9	133,713	174,253	2,282	480	11,873	2,762	0.995	25,959	25,959	11,927	100%	10	9	12,135	140.95	7,380
2024	20	240	9	120,760	157,549	2,027	480	10,735	2,507	0.9	25,959	25,959	11,927	100%	10	9	12,135	140.95	7,380
2026	20	240	9	110,639	144,170	1,805	480	9,823	2,285	0.824	25,959	25,959	11,927	100%	10	9	12,135	140.95	7,380
2028	20	240	9	103,123	134,040	1,627	480	9,133	2,107	0.766	25,959	25,959	11,927	100%	10	9	12,135	140.95	7,380
2030	20	240	9	97,448	126,411	1,493	480	8,613	1,973	0.722	25,959	25,959	11,927	100%	10	9	12,135	140.95	7,380
2032	20	240	9	95,370	123,660	1,448	480	8,426	1,928	0.706	25,959	25,959	11,927	100%	10	9	12,135	140.95	7,380
2034	20	240	9	93,956	121,759	1,414	480	8,296	1,894	0.696	25,959	25,959	11,927	100%	10	9	12,135	140.95	7,380
2036	20	240	9	92,582	119,993	1,388	480	8,176	1,868	0.686	25,959	25,959	11,927	100%	10	9	12,135	140.95	7,380
2038	20	240	9	91,525	118,593	1,364	480	8,080	1,844	0.678	25,959	25,959	11,927	100%	10	9	12,135	140.95	7,380
2040	20	240	9	90,526	117,273	1,342	480	7,990	1,822	0.67	25,959	25,959	11,927	100%	10	9	12,135	140.95	7,380
2042	20	240	9	89,466	115,869	1,319	480	7,895	1,799	0.662	25,959	25,959	11,927	100%	10	9	12,135	140.95	7,380
2044	20	240	9	88,436	114,506	1,296	480	7,802	1,776	0.654	25,959	25,959	11,927	100%	10	9	12,135	140.95	7,380
2046	20	240	9	87,430	113,176	1,274	480	7,711	1,754	0.647	25,959	25,959	11,927	100%	10	9	12,135	140.95	7,380
2048	20	240	9	86,252	111,687	1,253	480	7,610	1,733	0.638	25,959	25,959	11,927	100%	10	9	12,135	140.95	7,380
2050	20	240	9	85,496	110,627	1,232	480	7,538	1,712	0.632	25,959	25,959	11,927	100%	10	9	12,135	140.95	7,380
Sunshot	20	240	9	60,002	79,079	820	480	5,388	1,300	0.452	25,959	25,959	11,927	100%	10	9	12,135	140.95	7,380

Accelerated Technology Improvement - Westchester Residential (100% Load Met)

Battery Projection Study	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Battery Autonomy	Battery Throughput
	kW		kW	$	$	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	hr	kWh/yr
Bloomberg New Energy Finance	20	240	9	123,897	168,601	2,566	480	11,488	3,046	0.963	25,959	25,959	11,927	100%	10	9	12,135	140.95	7,380
Deutsche Bank	20	240	9	90,002	121,111	1,640	480	8,252	2,120	0.692	25,959	25,959	11,927	100%	10	9	12,135	140.95	7,380
McKinsey	20	240	9	78,002	104,298	1,312	480	7,106	1,792	0.596	25,959	25,959	11,927	100%	10	9	12,135	140.95	7,380
Department of Energy	20	240	9	60,002	79,079	820	480	5,388	1,300	0.452	25,959	25,959	11,927	100%	10	9	12,135	140.95	7,380
Battery OEM	20	240	9	54,002	70,673	656	480	4,815	1,136	0.404	25,959	25,959	11,927	100%	10	9	12,135	140.95	7,380

Demand-side Improvement - Westchester Residential (98% Load Met)

Year	PV	1kWh Li-ion	Converter	Efficiency Case	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Battery Autonomy	Battery Throughput
	kW		kW		$	$	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	hr	kWh/yr
2014	18	65	7	Yes	76,372	88,440	1,079	130	8,858	1,209	1.08	23,363	23,363	8,205	1	172	150	13,899	38.17	4,876
2016	18	65	7	Yes	65,431	76,947	930	130	7,086	1,060	0.864	23,363	23,363	8,205	1	172	150	13,899	38.17	4,876
2018	18	65	7	Yes	83,473	97,939	886	130	6,879	1,016	0.838	23,363	23,363	8,205	1	172	150	13,899	38.17	4,876
2020	18	65	7	Yes	75,037	88,643	797	130	6,040	927	0.736	23,363	23,363	8,205	1	172	150	13,899	38.17	4,876
2022	18	65	7	Yes	67,904	80,382	720	130	5,477	850	0.668	23,363	23,363	8,205	1	172	150	13,899	38.17	4,876
2024	14	85	8	Yes	58,991	73,519	820	170	5,009	990	0.611	18,171	18,171	8,205	1	172	150	8,679	49.92	5,006
2026	14	85	8	Yes	54,714	68,089	741	170	4,639	911	0.565	18,171	18,171	8,205	1	172	150	8,679	49.92	5,006
2028	14	85	8	Yes	51,707	64,155	678	170	4,371	848	0.533	18,171	18,171	8,205	1	172	150	8,679	49.92	5,006
2030	14	85	8	Yes	49,420	61,177	631	170	4,168	801	0.508	18,171	18,171	8,205	1	172	150	8,679	49.92	5,006
2032	14	85	8	Yes	48,546	60,064	615	170	4,092	785	0.499	18,171	18,171	8,205	1	172	150	8,679	49.92	5,006
2034	14	85	8	Yes	47,976	59,322	603	170	4,042	773	0.493	18,171	18,171	8,205	1	172	150	8,679	49.92	5,006
2036	14	85	8	Yes	47,351	58,558	594	170	3,990	764	0.486	18,171	18,171	8,205	1	172	150	8,679	49.92	5,006
2038	14	85	8	Yes	46,907	57,993	585	170	3,951	755	0.482	18,171	18,171	8,205	1	172	150	8,679	49.92	5,006
2040	14	85	8	Yes	46,484	57,456	578	170	3,915	748	0.477	18,171	18,171	8,205	1	172	150	8,679	49.92	5,006
2042	14	85	8	Yes	46,040	56,890	569	170	3,876	739	0.472	18,171	18,171	8,205	1	172	150	8,679	49.92	5,006
2044	14	85	8	Yes	45,606	56,338	561	170	3,839	731	0.468	18,171	18,171	8,205	1	172	150	8,679	49.92	5,006
2046	14	85	8	Yes	45,180	55,798	553	170	3,802	723	0.463	18,171	18,171	8,205	1	172	150	8,679	49.92	5,006
2048	14	85	8	Yes	44,625	55,132	546	170	3,756	716	0.458	18,171	18,171	8,205	1	172	150	8,679	49.92	5,006
2050	14	85	8	Yes	44,357	54,757	539	170	3,731	709	0.455	18,171	18,171	8,205	1	172	150	8,679	49.92	5,006
Sunshot	14	85	8	Yes	31,731	39,986	392	170	2,724	562	0.332	18,171	18,171	8,205	1	172	150	8,679	49.92	5,006

Combined Improvement - Westchester Residential (98% Load Met)

Battery Projection Study	PV	1kWh Li-ion	Converter	Efficiency Case	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Battery Autonomy	Battery Throughput
	kW		kW		$	$	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	hr	kWh/yr
Bloomberg New Energy Finance	18	65	7	Yes	52536	66142	797	130	4507	927	0.549	23363	23363	8205	100%	172	150	13899	38.17	4876
Deutsche Bank	18	65	7	Yes	43356	53280	546	130	3630	676	0.442	23363	23363	8205	100%	172	150	13899	38.17	4876
McKinsey	18	65	7	Yes	40106	48726	457	130	3320	587	0.405	23363	23363	8205	100%	172	150	13899	38.17	4876
Department of Energy	14	85	8	Yes	31731	39986	392	170	2724	562	0.332	18171	18171	8205	100%	172	150	8679	49.92	5006
Battery OEM	14	85	8	Yes	29606	37009	334	170	2522	504	0.307	18171	18171	8205	100%	172	150	8679	49.92	5006

RESIDENTIAL TABLES - LOUISVILLE, KY

Base Case - Louisville Residential (100% Load Met)

Year	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Battery Autonomy	Battery Throughput
	kW		kW	$	$	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	hr	kWh/yr
2014	20	220	9	151,922	190,348	3,409	440	19,065	3,849	1.485	27,180	27,180	12,837	100%	13	11	12,340	120.02	7,722
2016	20	220	9	127,631	163,876	2,898	440	15,090	3,338	1.176	27,180	27,180	12,837	100%	13	11	12,340	120.02	7,722
2018	20	220	9	161,673	207,066	2,749	440	14,545	3,189	1.133	27,180	27,180	12,837	100%	13	11	12,340	120.02	7,722
2020	20	220	9	144,221	186,462	2,438	440	12,705	2,878	0.99	27,180	27,180	12,837	100%	13	11	12,340	120.02	7,722
2022	20	220	9	129,631	167,946	2,171	440	11,443	2,611	0.891	27,180	27,180	12,837	100%	13	11	12,340	120.02	7,722
2024	20	220	9	117,278	152,082	1,931	440	10,362	2,371	0.807	27,180	27,180	12,837	100%	13	11	12,340	120.02	7,722
2026	20	220	9	107,743	139,526	1,726	440	9,507	2,166	0.741	27,180	27,180	12,837	100%	13	11	12,340	120.02	7,722
2028	20	220	9	100,680	130,031	1,560	440	8,860	2,000	0.69	27,180	27,180	12,837	100%	13	11	12,340	120.02	7,722
2030	20	220	9	95,412	122,971	1,438	440	8,379	1,878	0.653	27,180	27,180	12,837	100%	13	11	12,340	120.02	7,722
2032	20	220	9	93,384	120,290	1,393	440	8,196	1,833	0.638	27,180	27,180	12,837	100%	13	11	12,340	120.02	7,722
2034	20	220	9	92,071	118,530	1,363	440	8,076	1,803	0.629	27,180	27,180	12,837	100%	13	11	12,340	120.02	7,722
2036	20	220	9	90,778	116,879	1,338	440	7,964	1,778	0.62	27,180	27,180	12,837	100%	13	11	12,340	120.02	7,722
2038	20	220	9	89,792	115,578	1,317	440	7,875	1,757	0.613	27,180	27,180	12,837	100%	13	11	12,340	120.02	7,722
2040	20	220	9	88,860	114,352	1,297	440	7,791	1,737	0.607	27,180	27,180	12,837	100%	13	11	12,340	120.02	7,722
2042	20	220	9	87,782	112,922	1,273	440	7,694	1,713	0.599	27,180	27,180	12,837	100%	13	11	12,340	120.02	7,722
2044	20	220	9	86,821	111,656	1,252	440	7,608	1,692	0.593	27,180	27,180	12,837	100%	13	11	12,340	120.02	7,722
2046	20	220	9	85,882	110,420	1,232	440	7,523	1,672	0.586	27,180	27,180	12,837	100%	13	11	12,340	120.02	7,722
2048	20	220	9	84,769	109,022	1,212	440	7,428	1,652	0.579	27,180	27,180	12,837	100%	13	11	12,340	120.02	7,722
2050	20	220	9	84,076	108,051	1,194	440	7,362	1,634	0.573	27,180	27,180	12,837	100%	13	11	12,340	120.02	7,722
Sunshot	20	220	9	59,120	77,257	796	440	5,264	1,236	0.41	27,180	27,180	12,837	100%	13	11	12,340	120.02	7,722

Accelerated Technology Improvement - Louisville Residential (100% Load Met)

Battery Projection Study	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Battery Autonomy	Battery Throughput
	kW		kW	$	$	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	hr	kWh/yr
Bloomberg New Energy Finance	20	220	9	117,691	159,318	2,396	440	10,855	2,836	0.846	27,180	27,180	12,837	100%	13	11	12,340	120.02	7,722
Deutsche Bank	20	220	9	86,620	115,786	1,547	440	7,889	1,987	0.615	27,180	27,180	12,837	100%	13	11	12,340	120.02	7,722
McKinsey	20	220	9	75,620	100,375	1,247	440	6,839	1,687	0.533	27,180	27,180	12,837	100%	13	11	12,340	120.02	7,722
Department of Energy	20	220	9	59,120	77,257	796	440	5,264	1,236	0.41	27,180	27,180	12,837	100%	13	11	12,340	120.02	7,722
Battery OEM	20	220	9	53,620	69,551	645	440	4,739	1,085	0.369	27,180	27,180	12,837	100%	13	11	12,340	120.02	7,722

Demand-side Improvement - Louisville Residential (98% Load Met)

Year	PV	1kWh Li-ion	Converter	Efficiency Case	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Battery Autonomy	Battery Throughput
	kW		kW		$	$	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	hr	kWh/yr
2014	17	60	6	Yes	73,577	85,584	1,083	120	8,572	1,203	0.97	23,103	23,103	8,836	1	182	157	12,938	32.73	5,112
2016	17	60	6	Yes	63,116	74,619	939	120	6,871	1,059	0.778	23,103	23,103	8,836	1	182	157	12,938	32.73	5,112
2018	17	60	6	Yes	80,570	95,050	897	120	6,677	1,017	0.756	23,103	23,103	8,836	1	182	157	12,938	32.73	5,112
2020	17	60	6	Yes	72,436	86,065	809	120	5,864	929	0.664	23,103	23,103	8,836	1	182	157	12,938	32.73	5,112
2022	17	60	6	Yes	65,580	78,096	733	120	5,321	853	0.602	23,103	23,103	8,836	1	182	157	12,938	32.73	5,112
2024	14	75	6	Yes	57,707	71,535	792	150	4,874	942	0.552	19,026	19,026	8,832	1	186	161	8,838	40.92	5,235
2026	14	75	6	Yes	53,709	66,495	721	150	4,531	871	0.513	19,026	19,026	8,832	1	186	161	8,838	40.92	5,235
2028	14	75	6	Yes	50,912	62,858	664	150	4,283	814	0.485	19,026	19,026	8,832	1	186	161	8,838	40.92	5,235
2030	14	75	6	Yes	48,829	60,164	622	150	4,099	772	0.464	19,026	19,026	8,832	1	186	161	8,838	40.92	5,235
2032	14	75	6	Yes	47,965	59,066	606	150	4,024	756	0.456	19,026	19,026	8,832	1	186	161	8,838	40.92	5,235
2034	14	75	6	Yes	47,445	58,394	596	150	3,979	746	0.45	19,026	19,026	8,832	1	186	161	8,838	40.92	5,235
2036	14	75	6	Yes	46,861	57,687	588	150	3,931	738	0.445	19,026	19,026	8,832	1	186	161	8,838	40.92	5,235
2038	14	75	6	Yes	46,453	57,172	580	150	3,895	730	0.441	19,026	19,026	8,832	1	186	161	8,838	40.92	5,235
2040	14	75	6	Yes	46,063	56,682	574	150	3,862	724	0.437	19,026	19,026	8,832	1	186	161	8,838	40.92	5,235
2042	14	75	6	Yes	45,595	56,082	565	150	3,821	715	0.433	19,026	19,026	8,832	1	186	161	8,838	40.92	5,235
2044	14	75	6	Yes	45,195	55,579	557	150	3,787	707	0.429	19,026	19,026	8,832	1	186	161	8,838	40.92	5,235
2046	14	75	6	Yes	44,803	55,085	551	150	3,753	701	0.425	19,026	19,026	8,832	1	186	161	8,838	40.92	5,235
2048	14	75	6	Yes	44,280	54,465	544	150	3,711	694	0.42	19,026	19,026	8,832	1	186	161	8,838	40.92	5,235
2050	14	75	6	Yes	44,044	54,134	537	150	3,688	687	0.418	19,026	19,026	8,832	1	186	161	8,838	40.92	5,235
Sunshot	14	75	6	Yes	31,567	39,573	395	150	2,696	545	0.305	19,026	19,026	8,832	1	186	161	8,838	40.92	5,235

Combined Improvement - Louisville Residential (98% Load Met)

Battery Projection Study	PV	1kWh Li-ion	Converter	Efficiency Case	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Battery Autonomy	Battery Throughput
	kW		kW		$	$	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	hr	kWh/yr
Bloomberg New Energy Finance	20	50	6	Yes	50754	62111	674	100	4232	774	0.479	27180	27180	8836	100%	181	157	17036	27.28	5015
Deutsche Bank	18	55	7	Yes	42122	51368	520	110	3500	630	0.396	24462	24462	8835	100%	183	159	14307	30.01	5076
McKinsey	17	60	6	Yes	38692	47310	467	120	3223	587	0.365	23103	23103	8836	100%	182	157	12938	32.73	5112
Department of Energy	14	75	6	Yes	31567	39573	395	150	2696	545	0.305	19026	19026	8832	100%	186	161	8838	40.92	5235
Battery OEM	13	80	8	Yes	29052	36798	368	160	2507	528	0.284	17667	17667	8831	100%	188	162	7468	43.65	5285

RESIDENTIAL TABLES - SAN ANTONIO, TX

Base Case - San Antonio Residential (100% Load Met)

Year	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Battery Autonomy	Battery Throughput
	kW		kW	$	$	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	hr	kWh/yr
2014	20	220	12	148,866	186,227	3,302	440	18,653	3,742	1.223	31,030	31,030	15,247	100%	12	10	13,370	101.07	9,124
2016	20	220	12	124,934	160,124	2,800	440	14,745	3,240	0.967	31,030	31,030	15,247	100%	12	10	13,370	101.07	9,124
2018	20	220	12	158,168	202,204	2,653	440	14,203	3,093	0.932	31,030	31,030	15,247	100%	12	10	13,370	101.07	9,124
2020	20	220	12	141,075	182,055	2,352	440	12,404	2,792	0.814	31,030	31,030	15,247	100%	12	10	13,370	101.07	9,124
2022	20	220	12	126,755	163,917	2,092	440	11,168	2,532	0.733	31,030	31,030	15,247	100%	12	10	13,370	101.07	9,124
2024	20	220	12	114,581	148,304	1,858	440	10,105	2,298	0.663	31,030	31,030	15,247	100%	12	10	13,370	101.07	9,124
2026	20	220	12	105,136	135,874	1,654	440	9,258	2,094	0.607	31,030	31,030	15,247	100%	12	10	13,370	101.07	9,124
2028	20	220	12	98,163	126,505	1,491	440	8,619	1,931	0.565	31,030	31,030	15,247	100%	12	10	13,370	101.07	9,124
2030	20	220	12	92,895	119,445	1,369	440	8,138	1,809	0.534	31,030	31,030	15,247	100%	12	10	13,370	101.07	9,124
2032	20	220	12	90,957	116,890	1,327	440	7,964	1,767	0.522	31,030	31,030	15,247	100%	12	10	13,370	101.07	9,124
2034	20	220	12	89,644	115,130	1,296	440	7,844	1,736	0.515	31,030	31,030	15,247	100%	12	10	13,370	101.07	9,124
2036	20	220	12	88,351	113,479	1,272	440	7,732	1,712	0.507	31,030	31,030	15,247	100%	12	10	13,370	101.07	9,124
2038	20	220	12	87,365	112,178	1,251	440	7,643	1,691	0.501	31,030	31,030	15,247	100%	12	10	13,370	101.07	9,124
2040	20	220	12	86,433	110,952	1,231	440	7,560	1,671	0.496	31,030	31,030	15,247	100%	12	10	13,370	101.07	9,124
2042	20	220	12	85,445	109,648	1,209	440	7,471	1,649	0.49	31,030	31,030	15,247	100%	12	10	13,370	101.07	9,124
2044	20	220	12	84,484	108,382	1,188	440	7,385	1,628	0.484	31,030	31,030	15,247	100%	12	10	13,370	101.07	9,124
2046	20	220	12	83,545	107,146	1,168	440	7,300	1,608	0.479	31,030	31,030	15,247	100%	12	10	13,370	101.07	9,124
2048	20	220	12	82,432	105,747	1,149	440	7,205	1,589	0.473	31,030	31,030	15,247	100%	12	10	13,370	101.07	9,124
2050	20	220	12	81,739	104,777	1,130	440	7,139	1,570	0.468	31,030	31,030	15,247	100%	12	10	13,370	101.07	9,124
Sunshot	20	220	12	57,502	74,990	752	440	5,109	1,192	0.335	31,030	31,030	15,247	100%	12	10	13,370	101.07	9,124

Accelerated Technology Improvement - San Antonio Residential (100% Load Met)

Battery Projection Study	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Battery Autonomy	Battery Throughput
	kW		kW	$	$	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	hr	kWh/yr
Bloomberg New Energy Finance	20	220	12	116,073	157,052	2,352	440	10,701	2,792	0.702	31,030	31,030	15,247	100%	12	10	13,370	101.07	9,124
Deutsche Bank	20	220	12	85,002	113,520	1,503	440	7,735	1,943	0.507	31,030	31,030	15,247	100%	12	10	13,370	101.07	9,124
McKinsey	20	220	12	74,002	98,108	1,202	440	6,685	1,642	0.438	31,030	31,030	15,247	100%	12	10	13,370	101.07	9,124
Department of Energy	20	220	12	57,502	74,990	752	440	5,109	1,192	0.335	31,030	31,030	15,247	100%	12	10	13,370	101.07	9,124
Battery OEM	20	220	12	52,002	67,284	601	440	4,584	1,041	0.301	31,030	31,030	15,247	100%	12	10	13,370	101.07	9,124

Demand-side Improvement - San Antonio Residential (98% Load Met)

Year	PV	1kWh Li-ion	Converter	Efficiency Case	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Battery Autonomy	Battery Throughput
	kW		kW		$	$	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	hr	kWh/yr
2014	18	60	7	Yes	74,231	85,735	1,032	120	8,587	1,152	0.819	27,927	27,927	10,488	1	218	192	15,837	27.57	6,026
2016	18	60	7	Yes	63,689	74,714	895	120	6,880	1,015	0.656	27,927	27,927	10,488	1	218	192	15,837	27.57	6,026
2018	18	60	7	Yes	81,284	95,152	854	120	6,684	974	0.637	27,927	27,927	10,488	1	218	192	15,837	27.57	6,026
2020	18	60	7	Yes	73,110	86,199	772	120	5,873	892	0.56	27,927	27,927	10,488	1	218	192	15,837	27.57	6,026
2022	18	60	7	Yes	66,193	78,242	701	120	5,331	821	0.508	27,927	27,927	10,488	1	218	192	15,837	27.57	6,026
2024	14	80	8	Yes	57,475	71,651	806	160	4,882	966	0.465	21,721	21,721	10,495	1	214	185	9,590	36.75	6,190
2026	14	80	8	Yes	53,368	66,458	732	160	4,528	892	0.431	21,721	21,721	10,495	1	214	185	9,590	36.75	6,190
2028	14	80	8	Yes	50,496	62,715	673	160	4,273	833	0.407	21,721	21,721	10,495	1	214	185	9,590	36.75	6,190
2030	14	80	8	Yes	48,311	59,878	628	160	4,080	788	0.389	21,721	21,721	10,495	1	214	185	9,590	36.75	6,190
2032	14	80	8	Yes	47,471	58,815	613	160	4,007	773	0.382	21,721	21,721	10,495	1	214	185	9,590	36.75	6,190
2034	14	80	8	Yes	46,927	58,108	602	160	3,959	762	0.377	21,721	21,721	10,495	1	214	185	9,590	36.75	6,190
2036	14	80	8	Yes	46,322	57,373	593	160	3,909	753	0.372	21,721	21,721	10,495	1	214	185	9,590	36.75	6,190
2038	14	80	8	Yes	45,896	56,832	585	160	3,872	745	0.369	21,721	21,721	10,495	1	214	185	9,590	36.75	6,190
2040	14	80	8	Yes	45,490	56,319	578	160	3,837	738	0.366	21,721	21,721	10,495	1	214	185	9,590	36.75	6,190
2042	14	80	8	Yes	45,063	55,778	570	160	3,800	730	0.362	21,721	21,721	10,495	1	214	185	9,590	36.75	6,190
2044	14	80	8	Yes	44,647	55,250	562	160	3,764	722	0.359	21,721	21,721	10,495	1	214	185	9,590	36.75	6,190
2046	14	80	8	Yes	44,238	54,733	555	160	3,729	715	0.355	21,721	21,721	10,495	1	214	185	9,590	36.75	6,190
2048	14	80	8	Yes	43,699	54,090	548	160	3,685	708	0.351	21,721	21,721	10,495	1	214	185	9,590	36.75	6,190
2050	14	80	8	Yes	43,447	53,737	541	160	3,661	701	0.349	21,721	21,721	10,495	1	214	185	9,590	36.75	6,190
Sunshot	14	80	8	Yes	31,135	39,407	404	160	2,685	564	0.256	21,721	21,721	10,495	1	214	185	9,590	36.75	6,190

Combined Improvement - San Antonio Residential (98% Load Met)

Battery Projection Study	PV	1kWh Li-ion	Converter	Efficiency Case	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Battery Autonomy	Battery Throughput
	kW		kW		$	$	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	hr	kWh/yr
Bloomberg New Energy Finance	18	60	7	Yes	50608	63698	772	120	4340	892	0.414	27927	27927	10488	100%	218	192	15837	27.57	6026
Deutsche Bank	18	60	7	Yes	42135	51825	540	120	3531	660	0.337	27927	27927	10488	100%	218	192	15837	27.57	6026
McKinsey	18	60	7	Yes	39135	47622	458	120	3245	578	0.309	27927	27927	10488	100%	218	192	15837	27.57	6026
Department of Energy	14	80	8	Yes	31135	39407	404	160	2685	564	0.256	21721	21721	10495	100%	214	185	9590	36.75	6190
Battery OEM	14	80	8	Yes	29135	36605	349	160	2494	509	0.238	21721	21721	10495	100%	214	185	9590	36.75	6190

RESIDENTIAL TABLES - LOS ANGELES, CA

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Base Case - Los Angeles Residential (100% Load Met)

Year	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Battery Autonomy	Battery Throughput
	kW		kW	$	$	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	hr	kWh/yr
2014	10	65	5	54,907	65,945	976	130	6,605	1,106	0.835	16,057	16,057	7,914	100%	8	7	6,840	57.52	4,922
2016	10	65	5	46,526	56,924	827	130	5,242	957	0.662	16,057	16,057	7,914	100%	8	7	6,840	57.52	4,922
2018	10	65	5	59,128	72,138	784	130	5,067	914	0.64	16,057	16,057	7,914	100%	8	7	6,840	57.52	4,922
2020	10	65	5	52,932	65,040	695	130	4,431	825	0.56	16,057	16,057	7,914	100%	8	7	6,840	57.52	4,922
2022	10	65	5	47,719	58,699	618	130	3,999	748	0.505	16,057	16,057	7,914	100%	8	7	6,840	57.52	4,922
2024	10	65	5	43,386	53,350	549	130	3,635	679	0.459	16,057	16,057	7,914	100%	8	7	6,840	57.52	4,922
2026	10	65	5	40,186	49,268	489	130	3,357	619	0.424	16,057	16,057	7,914	100%	8	7	6,840	57.52	4,922
2028	10	65	5	37,921	46,295	441	130	3,154	571	0.399	16,057	16,057	7,914	100%	8	7	6,840	57.52	4,922
2030	10	65	5	36,201	44,046	404	130	3,001	534	0.379	16,057	16,057	7,914	100%	8	7	6,840	57.52	4,922
2032	10	65	5	35,547	43,209	392	130	2,944	522	0.372	16,057	16,057	7,914	100%	8	7	6,840	57.52	4,922
2034	10	65	5	35,118	42,648	383	130	2,906	513	0.367	16,057	16,057	7,914	100%	8	7	6,840	57.52	4,922
2036	10	65	5	34,654	42,078	376	130	2,867	506	0.362	16,057	16,057	7,914	100%	8	7	6,840	57.52	4,922
2038	10	65	5	34,322	41,653	370	130	2,838	500	0.359	16,057	16,057	7,914	100%	8	7	6,840	57.52	4,922
2040	10	65	5	34,006	41,250	364	130	2,811	494	0.355	16,057	16,057	7,914	100%	8	7	6,840	57.52	4,922
2042	10	65	5	33,673	40,824	357	130	2,782	487	0.351	16,057	16,057	7,914	100%	8	7	6,840	57.52	4,922
2044	10	65	5	33,348	40,409	351	130	2,753	481	0.348	16,057	16,057	7,914	100%	8	7	6,840	57.52	4,922
2046	10	65	5	33,030	40,003	345	130	2,726	475	0.344	16,057	16,057	7,914	100%	8	7	6,840	57.52	4,922
2048	10	65	5	32,619	39,508	339	130	2,692	469	0.34	16,057	16,057	7,914	100%	8	7	6,840	57.52	4,922
2050	10	65	5	32,414	39,221	334	130	2,672	464	0.338	16,057	16,057	7,914	100%	8	7	6,840	57.52	4,922
Sunshot	10	65	5	23,126	28,293	222	130	1,928	352	0.244	16,057	16,057	7,914	100%	8	7	6,840	57.52	4,922

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Accelerated Technology Improvement - Los Angeles Residential (100% Load Met)

Battery Projection Study	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Battery Autonomy	Battery Throughput
	kW		kW	$	$	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	hr	kWh/yr
Bloomberg New Energy Finance	10	65	5	40,431	52,538	695	130	3,580	825	0.452	16,057	16,057	7,914	100%	8	7	6,840	57.52	4,922
Deutsche Bank	10	65	5	31,251	39,677	444	130	2,703	574	0.342	16,057	16,057	7,914	100%	8	7	6,840	57.52	4,922
McKinsey	10	65	5	28,001	35,123	355	130	2,393	485	0.302	16,057	16,057	7,914	100%	8	7	6,840	57.52	4,922
Department of Energy	10	65	5	23,126	28,293	222	130	1,928	352	0.244	16,057	16,057	7,914	100%	8	7	6,840	57.52	4,922
Battery OEM	10	65	5	21,501	26,016	178	130	1,773	308	0.224	16,057	16,057	7,914	100%	8	7	6,840	57.52	4,922

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Demand-side Improvement - Los Angeles Residential (98% Load Met)

Year	PV	1kWh Li-ion	Converter	Efficiency Case	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Battery Autonomy	Battery Throughput
	kW		kW		$	$	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	hr	kWh/yr
2014	7	25	3	Yes	29,608	34,537	444	50	3,459	494	0.635	11,240	11,240	5,447	1	111	97	4,909	22.12	3,342
2016	7	25	3	Yes	25,376	30,117	387	50	2,773	437	0.509	11,240	11,240	5,447	1	111	97	4,909	22.12	3,342
2018	7	25	3	Yes	32,367	38,337	369	50	2,693	419	0.494	11,240	11,240	5,447	1	111	97	4,909	22.12	3,342
2020	7	25	3	Yes	29,101	34,753	335	50	2,368	385	0.435	11,240	11,240	5,447	1	111	97	4,909	22.12	3,342
2022	7	25	3	Yes	26,339	31,557	306	50	2,150	356	0.395	11,240	11,240	5,447	1	111	97	4,909	22.12	3,342
2024	6	30	4	Yes	23,320	28,914	321	60	1,970	381	0.362	9,634	9,634	5,444	1	115	100	3,298	26.55	3,389
2026	6	30	4	Yes	21,705	26,891	293	60	1,832	353	0.337	9,634	9,634	5,444	1	115	100	3,298	26.55	3,389
2028	6	30	4	Yes	20,590	25,450	271	60	1,734	331	0.319	9,634	9,634	5,444	1	115	100	3,298	26.55	3,389
2030	6	30	4	Yes	19,741	24,356	254	60	1,660	314	0.305	9,634	9,634	5,444	1	115	100	3,298	26.55	3,389
2032	6	30	4	Yes	19,411	23,942	249	60	1,631	309	0.3	9,634	9,634	5,444	1	115	100	3,298	26.55	3,389
2034	6	30	4	Yes	19,200	23,670	245	60	1,613	305	0.296	9,634	9,634	5,444	1	115	100	3,298	26.55	3,389
2036	6	30	4	Yes	18,958	23,379	241	60	1,593	301	0.293	9,634	9,634	5,444	1	115	100	3,298	26.55	3,389
2038	6	30	4	Yes	18,791	23,169	238	60	1,579	298	0.29	9,634	9,634	5,444	1	115	100	3,298	26.55	3,389
2040	6	30	4	Yes	18,631	22,969	236	60	1,565	296	0.287	9,634	9,634	5,444	1	115	100	3,298	26.55	3,389
2042	6	30	4	Yes	18,463	22,759	233	60	1,551	293	0.285	9,634	9,634	5,444	1	115	100	3,298	26.55	3,389
2044	6	30	4	Yes	18,300	22,553	230	60	1,537	290	0.282	9,634	9,634	5,444	1	115	100	3,298	26.55	3,389
2046	6	30	4	Yes	18,139	22,352	227	60	1,523	287	0.28	9,634	9,634	5,444	1	115	100	3,298	26.55	3,389
2048	6	30	4	Yes	17,922	22,096	224	60	1,505	284	0.277	9,634	9,634	5,444	1	115	100	3,298	26.55	3,389
2050	6	30	4	Yes	17,827	21,963	222	60	1,496	282	0.275	9,634	9,634	5,444	1	115	100	3,298	26.55	3,389
Sunshot	6	30	4	Yes	12,820	16,200	170	60	1,104	230	0.203	9,634	9,634	5,444	1	115	100	3,298	26.55	3,389

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Combined Improvement - Los Angeles Residential (98% Load Met)

Battery Projection Study	PV	1kWh Li-ion	Converter	Efficiency Case	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Battery Autonomy	Battery Throughput
	kW		kW		$	$	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	hr	kWh/yr
Bloomberg New Energy Finance	7	25	3	Yes	20351	26002	335	50	1772	385	0.325	11240	11240	5447	100%	111	97	4909	22.12	3342
Deutsche Bank	7	25	3	Yes	16820	21055	239	50	1435	289	0.263	11240	11240	5447	100%	111	97	4909	22.12	3342
McKinsey	7	25	3	Yes	15570	19304	204	50	1315	254	0.241	11240	11240	5447	100%	111	97	4909	22.12	3342
Department of Energy	6	30	4	Yes	12820	16199	170	60	1104	230	0.203	9634	9634	5444	100%	115	100	3298	26.55	3389
Battery OEM	6	30	4	Yes	12070	15149	150	60	1032	210	0.19	9634	9634	5444	100%	115	100	3298	26.55	3389

RESIDENTIAL TABLES - HONOLULU

Base Case - Honolulu Residential (100% Load Met)

Year	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Battery Autonomy	Battery Throughput
	kW		kW	$	$	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	hr	kWh/yr
2014	20	95	7	97,002	113,964	1,509	190	11,415	1,699	0.788	31,952	31,952	14,481	100%	11	10	15,318	45.95	8,069
2016	20	95	7	82,752	98,769	1,285	190	9,095	1,475	0.628	31,952	31,952	14,481	100%	11	10	15,318	45.95	8,069
2018	20	95	7	105,460	125,531	1,220	190	8,818	1,410	0.609	31,952	31,952	14,481	100%	11	10	15,318	45.95	8,069
2020	20	95	7	94,617	113,295	1,083	190	7,719	1,273	0.533	31,952	31,952	14,481	100%	11	10	15,318	45.95	8,069
2022	20	95	7	85,496	102,441	965	190	6,980	1,155	0.482	31,952	31,952	14,481	100%	11	10	15,318	45.95	8,069
2024	20	95	7	78,054	93,458	860	190	6,368	1,050	0.44	31,952	31,952	14,481	100%	11	10	15,318	45.95	8,069
2026	20	95	7	72,769	86,856	770	190	5,918	960	0.409	31,952	31,952	14,481	100%	11	10	15,318	45.95	8,069
2028	20	95	7	69,120	82,144	697	190	5,597	887	0.387	31,952	31,952	14,481	100%	11	10	15,318	45.95	8,069
2030	18	105	9	64,947	78,629	722	210	5,357	932	0.37	28,756	28,756	14,479	100%	13	11	12,107	50.79	8,154
2032	18	105	9	63,763	77,114	700	210	5,254	910	0.363	28,756	28,756	14,479	100%	13	11	12,107	50.79	8,154
2034	18	105	9	63,052	76,190	685	210	5,191	895	0.359	28,756	28,756	14,479	100%	13	11	12,107	50.79	8,154
2036	18	105	9	62,266	75,233	673	210	5,126	883	0.354	28,756	28,756	14,479	100%	13	11	12,107	50.79	8,154
2038	18	105	9	61,711	74,528	663	210	5,078	873	0.351	28,756	28,756	14,479	100%	13	11	12,107	50.79	8,154
2040	18	105	9	61,181	73,858	654	210	5,032	864	0.348	28,756	28,756	14,479	100%	13	11	12,107	50.79	8,154
2042	18	105	9	60,536	73,025	641	210	4,976	851	0.344	28,756	28,756	14,479	100%	13	11	12,107	50.79	8,154
2044	18	105	9	59,992	72,336	631	210	4,929	841	0.34	28,756	28,756	14,479	100%	13	11	12,107	50.79	8,154
2046	18	105	9	59,459	71,662	621	210	4,883	831	0.337	28,756	28,756	14,479	100%	13	11	12,107	50.79	8,154
2048	18	105	9	58,759	70,825	612	210	4,826	822	0.333	28,756	28,756	14,479	100%	13	11	12,107	50.79	8,154
2050	18	105	9	58,428	70,362	603	210	4,794	813	0.331	28,756	28,756	14,479	100%	13	11	12,107	50.79	8,154
Sunshot	18	105	9	41,745	50,741	403	210	3,457	613	0.239	28,756	28,756	14,479	100%	13	11	12,107	50.79	8,154

Accelerated Technology Improvement - Honolulu Residential (100% Load Met)

Battery Projection Study	PV	1kWh Li-ion	Converter	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Battery Autonomy	Battery Throughput
	kW		kW	$	$	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	hr	kWh/yr
Bloomberg New Energy Finance	20	95	7	68,427	86,627	1,050	190	5,902	1,240	0.408	31,952	31,952	14,481	100%	11	10	15,318	45.95	8,069
Deutsche Bank	20	95	7	55,010	67,829	683	190	4,622	873	0.319	31,952	31,952	14,481	100%	11	10	15,318	45.95	8,069
McKinsey	20	95	7	50,260	61,174	554	190	4,168	744	0.288	31,952	31,952	14,481	100%	11	10	15,318	45.95	8,069
Department of Energy	18	105	9	41,745	50,741	403	210	3,457	613	0.239	28,756	28,756	14,479	100%	13	11	12,107	50.79	8,154
Battery OEM	17	115	8	38,440	47,006	354	230	3,203	584	0.221	27,159	27,159	14,478	100%	14	12	10,500	55.63	8,203

Demand-side Improvement - Honolulu Residential (98% Load Met)

Year	PV	1kWh Li-ion	Converter	Efficiency Case	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Battery Autonomy	Battery Throughput
	kW		kW		$	$	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	hr	kWh/yr
2014	13	35	4	Yes	51,384	59,048	698	70	5,914	768	0.594	20,769	20,769	9,962	100%	209	181	9,343	16.93	5,497
2016	13	35	4	Yes	44,275	51,697	613	70	4,760	683	0.478	20,769	20,769	9,962	100%	209	181	9,343	16.93	5,497
2018	13	35	4	Yes	56,598	65,970	588	70	4,634	658	0.465	20,769	20,769	9,962	100%	209	181	9,343	16.93	5,497
2020	13	35	4	Yes	50,970	59,866	536	70	4,079	606	0.409	20,769	20,769	9,962	100%	209	181	9,343	16.93	5,497
2022	13	35	4	Yes	46,215	54,456	491	70	3,710	561	0.372	20,769	20,769	9,962	100%	209	181	9,343	16.93	5,497
2024	11	45	4	Yes	40,861	50,055	536	90	3,411	626	0.342	17,573	17,573	9,962	100%	211	181	6,126	21.77	5,601
2026	11	45	4	Yes	38,198	46,766	494	90	3,186	584	0.32	17,573	17,573	9,962	100%	211	181	6,126	21.77	5,601
2028	11	45	4	Yes	36,386	44,448	459	90	3,028	549	0.304	17,573	17,573	9,962	100%	211	181	6,126	21.77	5,601
2030	11	45	4	Yes	35,033	42,727	434	90	2,911	524	0.292	17,573	17,573	9,962	100%	211	181	6,126	21.77	5,601
2032	11	45	4	Yes	34,458	42,011	425	90	2,862	515	0.287	17,573	17,573	9,962	100%	211	181	6,126	21.77	5,601
2034	11	45	4	Yes	34,120	41,581	418	90	2,833	508	0.284	17,573	17,573	9,962	100%	211	181	6,126	21.77	5,601
2036	11	45	4	Yes	33,718	41,106	413	90	2,801	503	0.281	17,573	17,573	9,962	100%	211	181	6,126	21.77	5,601
2038	11	45	4	Yes	33,447	40,770	409	90	2,778	499	0.279	17,573	17,573	9,962	100%	211	181	6,126	21.77	5,601
2040	11	45	4	Yes	33,187	40,450	405	90	2,756	495	0.277	17,573	17,573	9,962	100%	211	181	6,126	21.77	5,601
2042	11	45	4	Yes	32,876	40,059	399	90	2,729	489	0.274	17,573	17,573	9,962	100%	211	181	6,126	21.77	5,601
2044	11	45	4	Yes	32,610	39,731	395	90	2,707	485	0.272	17,573	17,573	9,962	100%	211	181	6,126	21.77	5,601
2046	11	45	4	Yes	32,349	39,409	391	90	2,685	481	0.27	17,573	17,573	9,962	100%	211	181	6,126	21.77	5,601
2048	11	45	4	Yes	31,983	38,984	387	90	2,656	477	0.267	17,573	17,573	9,962	100%	211	181	6,126	21.77	5,601
2050	11	45	4	Yes	31,842	38,786	383	90	2,643	473	0.265	17,573	17,573	9,962	100%	211	181	6,126	21.77	5,601
Sunshot	11	45	4	Yes	22,971	28,652	297	90	1,952	387	0.196	17,573	17,573	9,962	100%	211	181	6,126	21.77	5,601

Combined Improvement - Honolulu Residential (98% Load Met)

Battery Projection Study	PV	1kWh Li-ion	Converter	Efficiency Case	Total Capital Cost	Total NPC	Total Annual Replacement Cost	Total O&M Cost	Total Annual Cost	Operating Cost	COE	PV Production	Total Electrical Production	AC Primary Load Served	Renewable Fraction	Capacity Shortage	Unmet Load	Excess Electricity	Battery Autonomy	Battery Throughput
	kW		kW		$	$	$/yr	$/yr	$/yr	$/yr	$/kWh	kWh/yr	kWh/yr	kWh/yr		kWh/yr	kWh/yr	kWh/yr	hr	kWh/yr
Bloomberg New Energy Finance	13	35	4	Yes	34040	42663	518	70	2907	588	0.292	20769	20769	9962	100%	209	181	9343	16.93	5497
Deutsche Bank	13	35	4	Yes	29096	35737	382	70	2435	452	0.244	20769	20769	9962	100%	209	181	9343	16.93	5497
McKinsey	13	35	4	Yes	27346	33285	335	70	2268	405	0.228	20769	20769	9962	100%	209	181	9343	16.93	5497
Department of Energy	11	45	4	Yes	22971	28652	297	90	1952	387	0.196	17573	17573	9962	100%	211	181	6126	21.77	5601
Battery OEM	9	60	5	Yes	20526	26870	312	120	1831	432	0.184	14378	14378	9963	100%	211	180	2901	29.02	5749

RESIDENTIAL TABLES - ALL LOCATIONS

Residential (All Scenario and Geography) Financial Costs							
Year	PV Capital Cost	PV Replacement Cost	Li-ion Battery Capital Cost	Li-ion Battery Replacement Cost	Inverter Capital Cost	Inverter 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
Sunshot	1.5	1.5	125	125	0.18	0.18	4.6

Residential (Accelerated Technology and Combined Improvement Scenario) All Geography Financial Costs						
Battery Projection Study	PV Capital Cost	PV Replacement Cost	Li-ion Battery Capital Cost	Li-ion Battery Replacement Cost	Inverter Capital Cost	Inverter Replacement Cost
	$/Wdc	$/Wdc	$/kWh	$/kWh	$	$
Bloomberg New Energy Finance	1.5	1.5	391.23	391.23	0.18	0.18
Deutsche Bank	1.5	1.5	250	250	0.18	0.18
McKinsey	1.5	1.5	200	200	0.18	0.18
Department of Energy	1.5	1.5	125	125	0.18	0.18
Battery OEM	1.5	1.5	100	100	0.18	0.18

ENDNOTES

ENDNOTES

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A Farewell to Fossil Fuels

Answering the Energy Challenge

Amory B. Lovins

Nearly 90 percent of the world's economy is fueled every year by digging up and burning about four cubic miles of the rotted remains of primeval swamp goo. With extraordinary skill, the world's most powerful industries have turned that oil, gas, and coal into affordable and convenient fuels and electricity that have created wealth, helped build modern civilization, and enriched the lives of billions.

Yet today, the rising costs and risks of these fossil fuels are undercutting the security and prosperity they have enabled. Each day, the United States spends about $2 billion buying oil and loses another $4 billion indirectly to the macroeconomic costs of oil dependence, the microeconomic costs of oil price volatility, and the cost of keeping military forces ready for intervention in the Persian Gulf.

In all, the United States spends one-sixth of its GDP on oil, not counting any damage to foreign policy, global stability, public health, and the environment. The hidden costs are also massive for coal and are significant for natural gas, too. Even if oil and coal prices were not high, volatile, and rising, risks such as fuel insecurity and dependence, pollution-caused illnesses, energy-driven conflicts over water and food, climate change, and geopolitical tensions would make oil and coal unattractive.

Weaning the United States from those fossil fuels would require two big shifts: in oil and electricity. These are distinct—nearly half

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of electricity is made from coal, and almost none is made from oil—but power plants and oil burning each account for over two-fifths of the carbon that is emitted by fossil-fuel use. In the United States, three-fourths of electricity powers buildings, three-fourths of oil fuels transportation, and the remaining oil and electricity run factories. So saving oil and electricity is chiefly about making buildings, vehicles, and factories far more efficient—no small task.

But epochal energy shifts have happened before. In 1850, most U.S. homes used whale-oil lamps, and whaling was the country's fifth-biggest industry. But as whale populations dwindled, the price of whale oil rose, so between 1850 and 1859, coal-derived synthetic fuels grabbed more than five-sixths of the lighting market. In 1859, Edwin Drake struck oil, and kerosene, thanks to generous tax breaks, soon took over. Whalers, astounded that they had run out of customers before they ran out of whales, begged for federal subsidies on national security grounds, but Thomas Edison's 1879 invention of electric lighting snuffed out their industry. Whales had been accidentally saved by technological innovators and profit-maximizing capitalists.

As the world shuddered from the 1973 oil shock, the economist Phil Gramm predicted that just as with whale oil, innovators would innovate, capitalists would invest, markets would clear, and substitutes for petroleum would ultimately emerge. He was right. By 2010, the United States was using 60 percent less oil to make $1 of GDP than it had in 1975. Now, the other shoe is dropping: since its use in the United States peaked in 2005, coal has lost one-fourth of its share of the U.S. electric services market to renewable energy, natural gas, and efficient use. After just a few centuries, the anomalous era of oil and coal is gradually starting to come to an end. In its place, the era of everlasting energy is dawning.

Underlying this shift in supply is the inexorable shrinkage in the energy needed to create $1 of GDP. In 1976, I heretically suggested in these pages that this "energy intensity" could fall by two-thirds by 2025. By 2010, it had fallen by half, driven by no central plan or visionary intent but only by the perennial quest for profit, security, and health. Still-newer methods, without further inventions, could reduce U.S. energy intensity by another two-thirds over the next four decades, with huge economic benefits. In fact, as *Reinventing Fire*, the new book from my organization, Rocky Mountain Institute (RMI), details, a U.S. economy that has grown by 158 percent by 2050 could need no oil, no coal, no nuclear energy, and one-third less natural gas—and cost $5 trillion less than business as usual, ignoring all hidden costs. Today's fossil carbon emissions could also fall by more than four-fifths without even putting a price on them.

This transformation requires pursuing three agendas. First, radical automotive efficiency can make electric propulsion affordable; heavy vehicles, too, can save most of their fuel; and all vehicles can be used more productively. Second, new designs can make buildings and factories several times as efficient as they are now. Third, modernizing the electric system to make it diverse, distributed, and renewable can also make it clean, reliable, and secure. These ambitious shifts may seem quixotic, but sometimes tough problems are best solved by enlarging their boundaries, as General Dwight Eisenhower reputedly advised.

Thus, it is easier to solve the problems of all four energy-using sectors—transportation, buildings, industry, and electricity—together than separately. For example, electric vehicles could recharge from or supply power to the electricity grid at times that compensate for variations in the output from wind and solar power. Synergies likewise arise from integrating innovations in technology, policy, design, and strategy, not just the first one or two.

This transition will require no technological miracles or social engineering—only the systematic application of many available, straightforward techniques. It could be led by business for profit and sped up by revenue-neutral policies enacted by U.S. states or federal agencies, and it would need from Congress no new taxes, subsidies, mandates, or laws. The United States' most effective institutions—the private sector, civil society, and the military—could bypass its least effective institutions. At last, Americans could make energy do their work without working their undoing.

MOBILITY WITHOUT OIL

THE UNITED STATES burns one-fourth of the world's oil, half in automobiles (which comprise cars and light trucks). Two-thirds of cars' fuel use is caused by their weight, yet for the past quarter century, U.S.

cars have gained weight twice as fast as their drivers. Now, lighter metals and synthetic materials are reversing automotive obesity. Ultralight, ultrastrong carbon-fiber composites can trigger dramatic weight savings, improve safety, and offset the carbon fiber's higher cost with simpler automaking (needing four-fifths less capital) and smaller powertrains. In 2011, lightweighting became the auto industry's hottest trend. Ford's strategy rests on it, and the United States could lead it. So far, however, Germany has taken the lead: Volkswagen, BMW, and Audi all plan to be mass-producing carbon-fiber electric cars by 2013.

Ultralight, aerodynamic autos make electric propulsion affordable because they need fewer costly batteries or fuel cells. Rather than wringing pennies from old steel-stamping and engine technologies, automakers could exploit mutually reinforcing advances in carbon fiber, its structural manufacturing, and electric propulsion—a transition as game changing as the shift from typewriters to computers. BMW, whose chief executive has said, "We do not intend to be a typewriter-maker," has confirmed that its planned 2013 electric car will pay for its carbon fiber by needing fewer batteries.

Electric autos are already far cheaper to fuel than gasoline autos, and they could also cost about the same to buy within a few decades. Until then, "feebates"—rebates for more efficient new autos, paid for by equivalent fees on inefficient ones—could prevent sticker shock. In just two years, France, with the biggest of Europe's five feebate programs, saw its new autos get more efficient three times as fast as before. Well-designed U.S. feebates, which could be enacted at the state level, need not cost the government a penny. They could expand customers' choices and boost automakers' and dealers' profit margins.

Autos could also be used more productively. If the government employed new methods to charge drivers for road infrastructure by the mile, its insolvent Highway Trust Fund would not need to rely on taxing dwindling gallons of fuel. Information technologies could smooth traffic flow, enhance public transit, and promote vehicle- and ridesharing. Better-designed layouts of communities could increase affordability, livability, and developers' profits. Together, these proven innovations could get Americans to their destinations with half the driving (or less) and $0.4 trillion less cost.

Rmi's analysis found that by 2050, the United States could deliver far greater mobility by making vehicles efficient, productive, and oil-free. Autos powered by any mix of electricity, hydrogen fuel cells, and advanced biofuels could get the equivalent of 125 to 240 miles per gallon of gasoline and save trillions of dollars. By 2050, "drilling under Detroit" could profitably displace nearly 15 million barrels of oil per day—1.5 times as much as Saudi Arabia's current daily output.

Heavy vehicles present similar opportunities. From 2005 to 2010, Walmart saved 60 percent of its heavy-truck fleet's fuel through smarter designs and changes in driver behavior and logistics. Aeronautical engineers are designing airplanes that will be three to five times as efficient as today's. Superefficient trucks and airplanes could use advanced biofuels or hydrogen, or trucks could burn natural gas, but no vehicles would need oil. Advanced biofuels, two-thirds made from waste, would require no cropland, protecting soil and the climate. The U.S. military's ongoing advances in efficiency will speed all these innovations in the civilian sector, which uses over 50 times as much oil, just as military research and development created the Internet, gps, and the microchip and jet-engine industries.

U.S. gasoline demand peaked in 2007; the oil use of the countries of the Organization for Economic Cooperation and Development peaked in 2005. With China and India pursuing efficient and electric vehicles, Deutsche Bank forecast in 2009 that world oil use could begin to decline after 2016. In fact, the world is nearing "peak oil"—not in supply but in demand. Oil is simply becoming uncompetitive even at low prices before it becomes unavailable even at high prices.

SAVING ELECTRICITY

The next big shift is to raise electricity productivity faster than the economy grows—starting with the United States' 120 million buildings. Even though U.S. buildings are projected to provide 70 percent more total floorspace in 2050, they could use far less energy. Investing an extra $0.5 trillion on existing or emerging energy-efficiency technologies and better-integrated designs could save building owners $1.9 trillion by tripling or quadrupling energy productivity. These straightforward improvements range from installing insulation, weather-stripping, and caulking to using more efficient equipment and controls, adopting better lighting design, and simply making new buildings the right shape and facing them in the right direction.

An even more powerful innovation, called "integrative design," can often save far more energy still, yet at lower cost. Integrative design optimizes a whole building, factory, vehicle, or device for multiple benefits, not isolated components for single benefits. For example, in 2010, the Empire State Building remanufactured its 6,514 windows onsite into "superwindows," which pass light but block heat. Requiring a third less air conditioning on hot days saved $17 million of the project's capital cost immediately, partly funding this and other improvements. In just three years, energy savings above 40 percent will repay the owners' total energy-saving investment.

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Integrative design's expanding returns are even more impressive when built in from scratch. From tropical to subarctic climates, new passively heated and cooled buildings can replace furnaces and air conditioners with superinsulation, heat recovery, and design that exploits the local climate. European companies have built 32,000 such structures at roughly normal capital cost and cost-effectively retrofitted similar performance into Swedish apartments constructed in the 1950s and into century-old Viennese apartments. The business case would be even stronger if it included the valuable indirect benefits of these more comfortable, pleasant, and healthful buildings: higher office labor productivity and retail sales, faster learning in classrooms, faster healing in hospitals, and higher real estate values everywhere.

Integrative design can also help double industrial energy productivity, saving $0.5 trillion. Pumps, for example, are the world's biggest user of electric motors. Pumps, motors, and controls can improve, but first replacing long, thin, crooked pipes with short, fat, straight ones often avoids 80–90 percent of the usual friction, saving ten times as much coal back at the power plant. When RMI and its industrial partners recently redesigned existing factories valued at more than $30 billion, our designs cut predicted energy use by about 30–60 percent with payback times of a few years. In new facilities, our designs were expected to save around 40–90 percent of energy use while usually reducing capital costs. This is not rocket science—just elegantly frugal whole-system thinking.

Adopting energy-saving innovations as quickly nationwide as some U.S. states do today will require patiently fixing perverse incentives, sharing benefits between landlords and tenants, allocating capital wisely, and designing thoughtfully—not just copying the old drawings ("infectious repetitis"). None of this barrier busting is easy, but the rewards are great. Since the Dow Chemical Company embraced efficiency innovation in the 1990s, its $1 billion investment has returned $9 billion. Savings and returns, far from petering out, often kept rising as the engineers learned new tricks faster than they exhausted old ones.

REPOWERING PROSPERITY

The United States must replace its aging, dirty, and insecure electric system by 2050 just to offset the loss of power plants that are being retired. Any replacement will cost about $6 trillion in net present value, whether it is more of the same, new nuclear power plants and "clean coal," or centralized or distributed renewable sources. But these differ profoundly in the kinds of risks they involve—in terms of security, safety, finance, technology, fuel, water, climate, and health—and in how they affect innovation, entrepreneurship, and customer choice.

Choosing electricity sources is complicated by copious disinformation, such as the myth that nuclear power was thriving in the United States until environmentalists derailed it after the March 1979 Three Mile Island meltdown. In fact, bad economics made orders for nuclear power plants in the United States fall by 90 percent from 1973 to 1975 and dry up completely by 1978. Indeed, soaring capital costs eventually halted nuclear expansion in all market-based power systems, and by 2010, all 66 reactors under construction worldwide had been bought by central planners.

Even after the U.S. government raised its subsidies for new reactors in 2005 to at least their construction costs, not one of the 34 proposed units could attract private capital; they simply had no business case. Neither do proposed "small modular reactors": nuclear reactors do not scale down well, and the economies sought from mass-producing hypothetical small reactors cannot overcome the head start enjoyed by small modular renewables, which have attracted \$1 trillion since 2004 and are adding another \$0.25 trillion a year. After the 2011 Fukushima nuclear disaster, John Rowe, chair of Exelon (the United States' biggest nuclear power producer), pronounced the nuclear renaissance dead. In truth, market forces had killed it years earlier.

New coal and nuclear plants are so uneconomical that official U.S. energy forecasts predict no new nuclear and few new coal projects will be launched. Investors are shunning their high costs and financial risks in favor of small, fast, modular renewable generators. These reduce the financial risk of building massive, slow, monolithic projects, and needing no fuel, they hedge against volatile gas prices. Already, wind and solar power's falling costs are beating fossil-fueled power's and nuclear power's rising costs. Some solar panels now sell wholesale for less than \$1 a watt (down 75 percent in three years), some installed solar-power systems in Germany sell for \$2.80 a watt, and some U.S. wind-power contracts charge less than three cents per kilowatt-hour—all far below recent forecasts. Solar power's plummeting cost, a stunning market success, is ruining some weaker or slower solar-cell-makers, but solar and wind power are extinguishing the prospects of coal and nuclear power around the world. So is cheap new natural gas—a valuable transitional resource if its many uncertainties can be resolved, but not a serious disappointment if they cannot, since higher efficiency and renewable energy should lower the demand for gas.

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Skeptics of solar and wind power warn of their fluctuating output. But the grid can cope. Just as it routinely backs up nonworking coal-fired and nuclear plants with working ones, it can back up becalmed wind turbines or darkened solar cells with flexible generators (renewable or not) in other places or of other kinds, or with systems that voluntarily modulate demand. Even with little or no bulk power storage, diversified, forecastable, and integrated renewables can prove highly reliable. Such integration into a larger, more diverse grid is how in 2010 Denmark had the capacity to produce 36 percent of its electricity from renewables, including 26 percent from wind (in an average wind year), and how four

German states were 43–52 percent wind-powered. But U.S. and European studies have shown how whole continents could make 80 percent or more of their power renewably by operating existing assets differently within smarter grids, in markets that clear faster and serve larger areas.

Diverse, dispersed, renewable sources can also make the grid highly resilient. Centralized grids are vulnerable to cascading blackouts caused by natural disaster, accident, or malice. But grid reorganizations in Denmark and Cuba have shown how prolonged regional blackouts become impossible when distributed renewables, bypassing vulnerable power lines (where most failures start), feed local "microgrids," which can stand alone if needed. The Pentagon, concerned about its own reliance on the commercial grid, shares this goal of resilience and this path to achieving it.

Individual households can also declare independence from power outages and utility bills, as mine has. In many parts of the United States, a private company can now install rooftop solar power with no money down and charge the customer less money per month to pay for it than the old electricity bill. These and other unregulated services could eventually create a "virtual utility" that could largely or wholly bypass power companies, just as cell phones bypassed landline phone companies—a prospect that worries utility executives but excites venture capitalists. Today, solar power is subsidized, although often less than fossil-fueled or nuclear plants and their fuel. But sooner than those rivals could be built, solar power should win out even without subsidies.

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In 2010, renewable sources, except for big hydropower dams, produced only three percent of the world's electricity, but for the third year running, they were responsible for nearly half of all new capacity. That same year, they won $151 billion of private investment and surpassed the total generating capacity of nuclear plants worldwide by adding over 60 billion watts of capacity. The world can now manufacture that much new photovoltaic capacity every year, outpacing even wind power.

The United States is a leader in developing renewable technology but lags in installing it. In June 2010 alone, Germany, with less sun than

Seattle, added 142 percent more solar-cell capacity than the United States did in all of 2010. Stop-and-go congressional policies sank U.S. clean-energy investments from first place globally to third between 2008 and 2010. (Federal initiatives expiring in 2011–12 temporarily restored the U.S. lead in 2011.) From 2005 to 2010, while the renewable fraction of the United States' electricity crawled from nine percent to ten percent, that of Portugal's soared from 17 percent to 45 percent. In 2010, congressional wrangling over the wind-power tax credit halved wind-power additions, while China doubled its wind capacity for the fifth year running and beat its 2020 target. The same year, 38 percent of China's net new capacity was renewable. China now leads the world in five renewable technologies and aims to in all.

Legacy industries erect many anticompetitive roadblocks to U.S. renewable energy, often denying renewable power fair access to the grid or rejecting cheaper wind power to shield old plants from competition. In 34 U.S. states, utilities earn more profit by selling more electricity and less if customers' bills fall. In 37 states, companies that reduce electricity demand are not allowed to bid in auctions for proposed new power supplies. But wherever such impediments are removed, efficiency and renewables win. In 2009, developers offered 4.4 billion watts of solar power cheaper than electricity from an efficient new gas-fired plant, so California's private utilities bought it—and in 2011, they were offered another 50 billion watts.

A COOLER AND SAFER WORLD

This new energy future offers a pragmatic solution to climate change. Often assumed to be costly, reducing carbon emissions is actually profitable, since saving fuel costs less than buying fuel. Profits, jobs, and competitive advantage make for easier conversations than costs, burdens, and sacrifices, and they need no global treaties to drive them.

In 2009, the consulting firm McKinsey & Company found that projected greenhouse gas emissions could be cut by 70 percent by 2030 at a trivial average cost of $6 per metric ton of carbon dioxide equivalent (the standard unit of global-warming impact). Including newer technologies and integrative designs could save even more carbon more cheaply, and thus could more than meet the United

States' obligations under the 1992 UN Framework Convention on Climate Change while saving $5 trillion.

Getting the United States off fossil fuels would transform its foreign policy. A world where the United States and other countries buy no oil because its price and price volatility exceed its value would have less oil-fed tyranny, corruption, terrorism, tension, and war. Washington, no longer needing an oil-centric foreign policy, could maintain normal relations with oil-exporting countries and treat diplomatic issues on their merits. The Pentagon would be pleased, too. Today, every one of the U.S. military's nine combatant commands must protect oil assets and transportation routes—fighting tanker-hijacking pirates off the coast of Somalia or pipeline-attacking militants from Latin America to Central Asia. The U.S. Army would love Mission Unnecessary in the Persian Gulf; the U.S. Navy would no longer need to worry as much about conflicts from the Arctic to the South China Sea. Proliferators, meanwhile, could no longer hide their intent behind civilian nuclear power in a world that acknowledged its marketplace collapse and the superiority of nonnuclear competitors. Nor could they draw on civilian skills, materials, and equipment.

Phasing out fossil fuels would turbocharge global development, which is also in the United States' interest. Energy inefficiency is one of the biggest causes of persistent poverty. Oil purchases underlie much of the developing world's debt, and wasted energy diverts meager national and household budgets. Developing countries are on average one-third as energy efficient as rich ones, and the poor often spend far more of their disposable income on energy than does the general population. Some 1.6 billion people live without electricity, leaving many basic needs unmet, hobbling health and development, and trapping women and girls in uneducated penury.

Investments in new electricity devour one-fourth of the world's development capital. There is no stronger nor more neglected lever for global development than investing instead in making devices that save electricity. This would require about one-thousandth the capital and return it ten times as fast, freeing up vast sums for other development needs. If the United States, Europe, China, and India merely adopted highly efficient lights, air conditioners, refrigerators, and TVs, they could save $1 trillion and 300 coal plants. That is the goal of the

Super-efficient Equipment and Appliance Deployment Initiative, an effort announced in 2009 and supported by 23 major countries.

Developing countries, with their rural villages, burgeoning cities and slums, and dilapidated infrastructures, especially need renewable electricity, and they now buy the majority of the world's new renewable capacity. Some remote villages are not waiting for the wires but leapfrogging the grid: more Kenyans are getting electricity first from solar-power entrepreneurs than from traditional utilities. Such efforts as the U.S. Department of Energy's Lumina Project have helped bring efficient and affordable solar-powered LED lights to millions across Africa. These projects improve education; free up kerosene budgets for mosquito nets, clean water, and other necessities; and could eventually prevent 1.5 million deaths from lung disease annually. Just by switching from kerosene lamps to fluorescent ones, one Indian village got 19 times as much light with one-ninth the energy and half the cost.

GETTING UNSTUCK

THE UNITED STATES cannot afford to keep waiting for a gridlocked Congress to act while the global clean-energy revolution passes it by. While U.S. fossil-fuel industries guard their parochial interests, Denmark is planning to get entirely off fossil fuels by 2050; Sweden has even aimed for 2020. Germany's campaign for renewables and energy efficiency helped push unemployment in the country to its lowest rate in a decade. German Chancellor Angela Merkel is winning her bet that the Russian company Gazprom is a less worthy recipient of German energy expenditures than German engineers, manufacturers, and installers. Brazil, Japan, and South Korea, meanwhile, are catching up in renewables. India has passed Japan and the United Kingdom in renewables investments and aims to rival China's global leadership in the sector.

As Washington's clean-energy research-and-development budget has shrunk, Beijing's has soared. In 2005, China's 11th five-year plan made lower energy intensity the top strategic priority for national development. In 2010, the 12th five-year plan launched a $0.8 trillion decarbonization effort, created the world's largest carbon-trading zone, and effectively capped China's carbon emissions. The country's net additions of coal plants fell by half between 2006 and 2010, and the overall efficiency of its coal plants pulled ahead of that of the United States'. No treaty compelled Beijing's leadership—just enlightened self-interest.

The United States' halfheartedness raises a conundrum: if the vision of an efficient clean-energy economy is so compelling, what keeps all U.S. citizens, firms, and institutions from embracing it as vigorously as a few states have? The answer is that markets outpace understanding, disinformation and parochial politics abound, and the road remains strewn with barriers, myths, and pervasive favoritism for incumbents. But must Thucydides' lament become Americans' fate—that each politician pursues self-advantage while "the common cause imperceptibly decays"?

The chief obstacle is not technology or economics but slow adoption. Helping innovations catch on will take education, leadership, and rapid learning. But it does not require reaching a consensus on motives. If Americans agree what should be done, then they need not agree why. Whether one cares most about national security, health, the environment, or simply making money, saving and supplanting fossil fuels makes sense.

Wise energy policy can grow from impeccably conservative roots—allowing and requiring all ways to save or produce energy to compete fairly at honest prices, regardless of their type, technology, size, location, or ownership. Who would oppose that? And what if the United States reversed the runaway energy-subsidy arms race, heading toward zero? Let those energy producers that insist they get no taxpayer largess explain why they are so loath to give it up.

Moving the United States off oil and coal will require Americans to trust in their own resourcefulness, ingenuity, and courage. These durable virtues can give the country fuel without fear; help set the world on a path beyond war, want, or waste; and turn energy from worrisome to worry-free, from risk to reward, from cost to profit.