



Benefits and Costs of Model Solar Applications for Local Governments

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This report was prepared by Frontier Associates in cooperation with the North Central Texas Council of Governments (NCTCOG), the State of Texas Energy Conservation Office (SECO), and the US Department of Energy (DOE). The contents of this report reflect the views of the authors who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the views or policies of the North Central Texas Council of Governments (NCTCOG), the State of Texas Energy Conservation Office (SECO), or the US Department of Energy (DOE).

List of Acronyms and Abbreviations

AC	alternating current
BC Ratio	benefit cost ratio
BOS	balance of system
CAIDI	Customer Average Interruption Duration Index
DC	direct current
DOE	US Department of Energy
ERCOT	Electric Reliability Council of Texas
ICE	Interruption Cost Estimate calculator
IRR	internal rate of return
JEDI	Jobs and Economic Development Impact model
kW	kilowatt
kWh	kilowatt-hour
MW	megawatt
MWh	megawatt-hour
NCTCOG	North Central Texas Council of Governments
NPV	net present value
NREL	National Renewable Energy Laboratories
PUCT	Public Utility Commission of Texas
PV	photovoltaic
PVC	polyvinyl chloride
REC	renewable energy credit
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SECO	Texas State Energy Conservation Office
TPO	thermoplastic overlay
US	United States
W	Watt

Executive Summary

As solar and energy storage technologies have become more cost competitive, local governments in Texas and elsewhere are increasingly involved in solar and storage projects. Direct involvement may include ownership or investment in assets that provide electricity to public facilities, provide backup power to critical public service infrastructure, or supply solar-generated electricity at wholesale to municipal electric utilities. Local governments also find themselves indirectly involved in solar projects initiated by citizens, such as rooftop solar on privately-owned homes and businesses, or larger scale solar developments intended to serve far away electricity customers; these projects interface with local planning and siting requirements, and have impacts on property assessments and tax revenues.

Due to these increased interactions between local governments and solar projects, NCTCOG members identified a need to develop consistent and comprehensive approaches to evaluating the benefits and costs of solar applications that may provide energy, capacity, shade, mobility, resiliency and other benefits to local communities. Model solar applications selected for detailed benefit-cost analysis included:

- Simple grid-tied solar
- Solar on landfills or other underutilized sites
- Solar on shading structures
- Grid-tied solar with energy storage
- Mobile solar with energy storage

This report recommends two types of benefit-cost analysis that local governments may conduct to evaluate proposed solar applications. The first is an analysis of all reasonably quantifiable financial benefits and costs expected to accrue to the local government performing the analysis.

Direct Financial Benefits

- Electric bill savings
 - Avoided energy inflows
 - Value of outflows
 - Avoided demand charges
- Increases in property tax revenue
- Value of shade/shelter
- Time of use arbitrage
- Renewable energy credits (RECs)

Direct Financial Costs

- Capital costs, net of
 - Utility incentives
 - Additional grants
 - Tax credits
- Operating and maintenance costs
- Financing costs

This report presents a customized financial pro forma model built using Microsoft Excel that is adaptable to a wide variety of solar and energy storage projects, and applies it to the model applications listed above. The model summarizes direct financial benefits and costs with a cash flow diagram and four key financial metrics:

- Internal rate of return (IRR)
- Net present value of cash flows (NPV)
- Simple payback years
- Benefit cost ratio

The second recommended benefit-cost analysis takes into account additional impacts that accrue to the community. Those impacts are also summarized using consistent metrics. Some impacts may be most properly accounted for within the direct financial benefits and costs analysis, within additional community impacts, or within both. For example, investments in solar shading structures may create opportunities for additional revenue (such as in a covered parking application) or may improve comfort and utilization of certain public facilities (such as covered areas at public parks). Public investments in solar and energy storage projects may:

- Impact local jobs and economic development;
- Reduce risk/exposure to volatile electricity rates;
- Carry environmental benefits such as reduced emissions;
- Provide shading over parking or public parks;
- Enable productive use of otherwise unusable public or private land;
- Provide or extend the capabilities of emergency services agencies or equipment during power outages;
- Make the distribution grid more resilient in the face of storms, fires or other natural events; or,
- Satisfy local goals of increasing public awareness about benefits of renewable energy sources.

Frontier analyzed the benefits and costs of selected solar and energy storage applications and produced financial pro forma tools to assist local governments in evaluating these technologies. Key findings are presented below.

- | | |
|--|---|
| General Findings | <ul style="list-style-type: none">• Solar and energy storage technologies are rapidly decreasing in cost due to technological and efficiency improvements and manufacturing scale, and are becoming increasingly cost-effective in local government applications in Texas.• Solar and energy storage technologies may be deployed in a wide variety of scales, applications, and contract structures that may be of interest to local governments.• Local government officials in Texas are increasingly coming into contact with solar and energy storage technologies, and could benefit from uniform, best-practice approaches to evaluating their benefits and costs. |
| Solar and Energy Storage in the Context of Energy Efficiency | <ul style="list-style-type: none">• Many conventional energy efficiency measures may be more cost-effective than investments in solar and energy storage, and should be investigated and prioritized by local governments looking to reduce energy costs. Reducing a facility's annual energy needs first has a subsequent benefit of reducing the size and cost of solar and energy storage systems needed to serve those needs.¹ |

¹ The State Energy Conservation Office (SECO) provides free energy audits as a resource for local governments through its [Preliminary Energy Assessment \(PEA\)](#) program.

- Cost-Effectiveness of Solar

 - Many simple grid-tied solar energy systems are currently cost-effective for local governments in Texas, particularly when direct costs are reduced with grants or utility incentives, or when equipment is leased or energy is purchased from a third party owner.
 - Additional direct value streams, such as those deriving from premiums on fee-based covered parking spaces, can improve the cost-effectiveness of potential solar investments.

- Cost-Effectiveness of Energy Storage

 - Energy storage technologies, when paired with solar generation, are not likely to be cost-effective in Texas currently as a strategy for managing demand or shifting energy consumption to less-expensive hours, but may become so within the next few years as costs decline and as market structures emerge to monetize storage-enabled services.

- Cost-Effectiveness of Mobile Solar plus Energy Storage

 - Mobile solar plus energy storage backup power units are unlikely to be cost-effective in Texas currently except in applications where anticipated loads are small, predictable, and often-utilized, such as for powering emergency signals and messaging signs.

- Best Practice Model Templates

 - Model applications and accompanying financial pro forma templates provided with this report may be adapted for use by local officials evaluating potential investments in solar and storage.

In addition to this report, Frontier Associates also prepared and delivered short case studies featuring model applications, and provided a copy of the Microsoft Excel modeling tool as a resource to be shared with local governments. Local governments are encouraged to utilize the models for their own purposes, and to contact Frontier Associates for technical assistance in adapting the models to specific use cases.

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1. Solar, Energy Storage, and Local Governments

The recent technological and economic trajectories of the solar and energy storage industries, combined with their broad diversity of potential applications, value streams, and deployment scales, mean that local governments² are increasingly coming into contact with solar and energy storage technologies.

Local government officials face new solar- and storage-related issues affecting the establishment of policy goals, the implementation of local permitting processes, the development of design requirements and technical specifications for new public and private construction, the procurement of energy via long-term contracts, and other public realms. The direction and decisions they provide affect not only how the local government acts as a potential consumer of solar and storage, but also how solar and energy storage are able to take root within the community as a whole.

This report provides guidance to local government officials as they seek to understand the benefits and costs of potential investments in solar and storage on public facilities, brownfields or other underutilized lands.

Here in section 1, the topic is introduced and context is provided by outlining some of the ways local governments are becoming involved solar and storage. Frontier describes the recent evolution of solar and storage markets, and summarizes the key components of various solar and solar plus storage systems. An overview of common financial structures used by local governments in procuring solar and storage systems, or the energy services provided by those systems, is also provided.

Section 2 proposes a methodology for analyzing benefits and costs associated with potential solar and storage investments. First, Frontier identifies the requirements of the benefit-cost analysis model, including key input and output metrics, and recommends analytical approaches for each output metric. A model is then constructed that separately analyzes direct financial benefits and costs (those which accrue directly to the public entity considering the potential investment in solar or storage), versus additional community impacts such as local jobs, economic development and environmental impact.

Section 3 identifies and describes five model solar applications likely to be of interest to local governments. We provide a general overview of each model application type, highlight a specific, real-world example, and define the input parameters of a hypothetical system and deal structure to be modeled with current cost and electric rate assumptions. Finally, we describe the results of those model runs, summarizing key direct financial metrics and additional community impacts.

Section 4 summarizes these results and provides key findings.

“
Local governments are increasingly coming into contact with solar and energy storage technologies.
”

² Within this report, the terms “local governments” and “local government officials” are used as shorthand to represent a wide variety of public or non-profit entities and their decision makers. These entities may include, but are not limited to, cities and counties, school districts, other special districts, public utilities or utility districts (such as municipal or rural electric cooperatives, water and wastewater utilities, landfill or other waste treatment facilities), emergency services agencies, state or federal agencies, and non-profit corporations.

The report was created by Frontier Associates (Frontier, www.frontierassoc.com), of Austin, Texas, with Steven M. Wiese, Senior Consultant in Efficiency and Renewable Energy, as the principal author. Additional project contributors and reviewers include Amy Martin, Jay Zarnikau, Kotomi Tomita, and Margaret Marchant at Frontier. The North Central Texas Council of Governments (NCTCOG, www.nctcog.org) contracted with Frontier in March 2016, and a final report was delivered in August 2016. Funding support for this project was provided by the Texas State Energy Conservation Office (SECO, seco.cpa.state.tx.us).

Additional resources for local governments interested in learning more about solar can be found at www.GoSolarTexas.org.

A Full Spectrum of Local Government Involvement

Local governments may affect development of solar energy in their communities and beyond through a variety of actions, including:

- Organizing and strategizing local solar efforts
- Maintaining solar affordability for residents and businesses
- Updating and enforcing local rules and regulations
- Improving utility policies and processes
- Creating jobs and supporting economic development
- Educating and empowering potential customers
- Leading by example with solar energy purchases and installations on public properties

The US Department of Energy publication [Solar Powering Your Community: A Guide for Local Governments](#) expands upon these general categories to identify and provide specific examples of more than 30 different types of local government solar initiatives. These are listed in Appendix A.

As an example of one North Central Texas community's recent efforts, the City of Plano's solar related initiatives are listed in Appendix B.

Rapidly declining solar prices have made solar a much more economically attractive option over the past several years, and public entities are increasingly tasked with requesting and evaluating proposals to supply or augment long term energy needs with solar. Therefore, this report primarily concentrates on the final category, "leading by example with solar energy purchases and installations on public properties," and identifies best practices for conducting benefit-cost analyses of model solar (or solar plus storage) applications deemed likely to be of interest to local governments. Further efforts by NCTCOG, SECO, and others address many of the additional solar-related actions likely to be considered by local governments. These work products may be found at www.GoSolarTexas.org.

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*Additional
information and
resources are
available at*



www.GoSolarTexas.org

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Solar's History and Recent Trends

The natural world has long transformed sunlight into usable forms of energy: plants harvest light to grow; animals warm themselves on surfaces exposed to sunlight. Humans began converting sunlight into electricity starting in 1839, when Sir Edmund Becquerel first demonstrated the photovoltaic effect in 1839 with an electrochemical cell. Today, solid-state devices based on Becquerel's discovery transform sunlight into electricity with greater efficiency and at lower cost than ever before, fueling major changes in how electricity is generated and distributed throughout the world, in the US, and here in Texas.

There are now over one million solar installations in the US. When accounting for new solar installations, both distributed and centralized, solar made up nearly 30 percent of all new electric generating capacity added in the US in 2015, exceeding the total for natural gas for the first time.³

“
Solar is more efficient and less costly than ever before, fueling major changes in how electricity is generated and distributed.
 ”

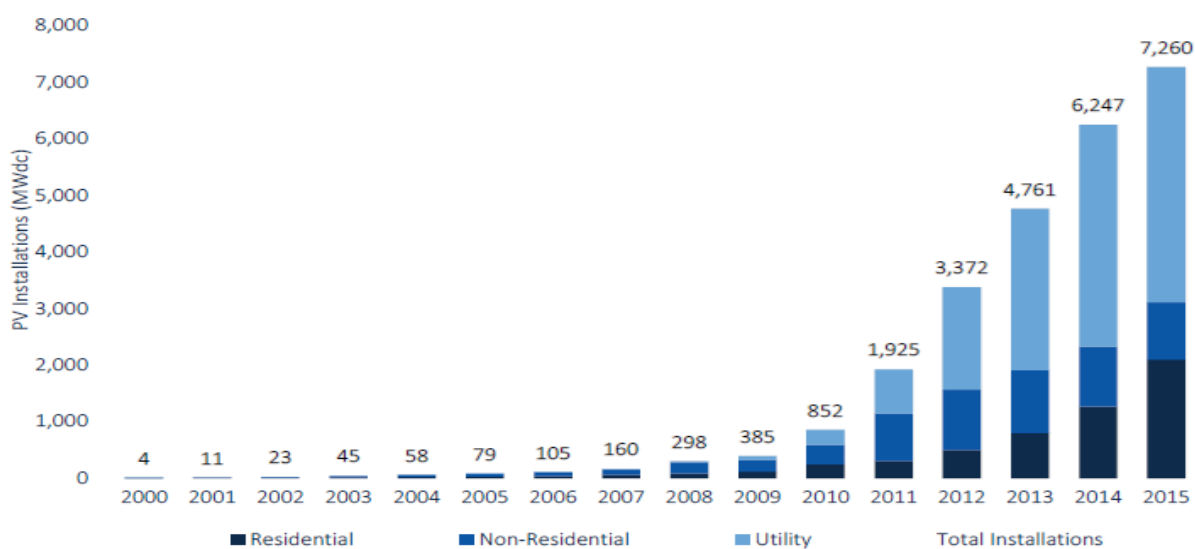


Figure 1. Annual US Solar PV Installations, 2000-2015⁴

³ US Solar Market Insight, Full Report, 2015 Year in Review, GTM Research, March 2016, p. 5.

⁴ Ibid.

Solar's recent growth is largely a result of its rapidly declining costs. Nationally, the installed retail price of solar energy systems decreased by more than half since 2009; installed costs of non-residential systems in Texas are among the lowest in the United States.

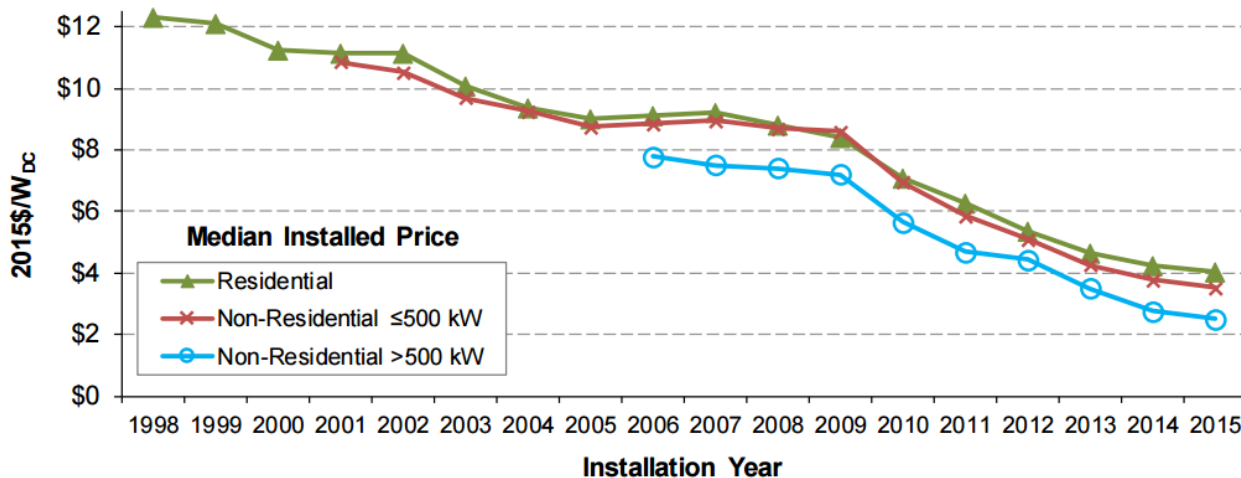


Figure 2. Solar Installed Costs, United States, 1998-2015⁵

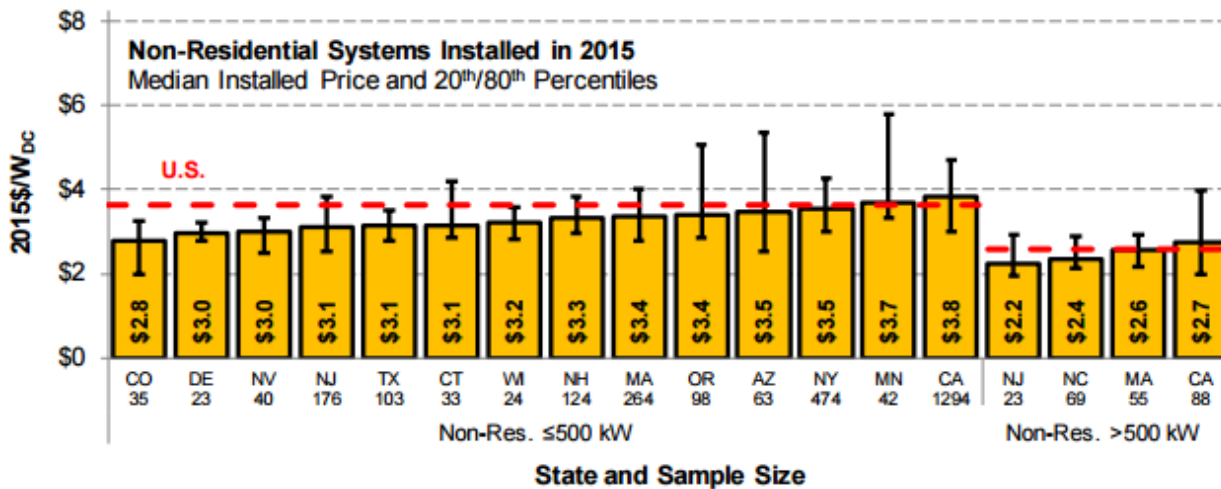


Figure 3. Solar Installed Costs by US State in 2015⁶

⁵ [Tracking the Sun IX: The Installed Price of Residential and Non-Residential Photovoltaic Systems in the United States](#), Lawrence Berkeley National Laboratory, August 2016, Summary presentation.

⁶ Ibid.

Many aspects of solar's recent ascendancy are global in nature, resulting from billions of dollars in invested capital, manufacturing at scale, and incremental technological improvements. Additionally, the maturation of a worldwide infrastructure of product manufacturers, wholesalers, dealers, system designers and installers make the process of evaluating and purchasing solar a more seamless experience for buyers.

But while the global solar marketplace is becoming enormous, solar is fundamentally a distributed energy technology dependent on an enormous⁷ but diffuse natural resource, and lends itself well to applications at every level:

- Utility-scale solar typically consists of thousands of solar panels covering hundreds of acres. They are deployed by utility generating companies to meet demand for electricity that may be located far from the generation source, with the electric transmission grid providing delivery. In Texas, there is currently more utility-scale solar capacity requesting interconnection to the state's main electric transmission system than generation from all other fuel types, including fossil fuels, combined.⁸ In addition, there are already 25 utility-scale solar energy systems comprising over 410 MW of generating capacity installed in Texas.⁹
- Commercial-scale solar consists of generating systems from a few kilowatts to a few megawatts of capacity that serve commercial, industrial, and public service or government-related electric loads, including those of schools, local government facilities, and other critical infrastructure. There are currently over 1,000 commercial solar energy systems comprising over 65 MW of generating capacity in Texas.¹⁰
- Residential-scale solar consists of smaller-scale generating systems designed to meet or supplement the electric energy needs of a single household; these tend to range from a few kilowatts up to about 20 kilowatts of capacity, with an average of about 8 kilowatts. There are currently over 14,000 residential solar energy systems comprising over 91 MW of generating capacity in Texas.¹¹

“
Solar lends itself well to applications at every scale – utility, commercial, and residential.
”

Electric Storage History and Current Trends

The recent history of the electric storage industry largely parallels that of the solar industry. Technical breakthroughs and increasing demand within a multitude of applications have led to improved storage efficiencies as well as rapidly declining costs. Declining costs, in turn, have opened new markets in which storage can potentially compete with other resources, increasing demand and starting the cycle all over again.

⁷ Due to its large land area and excellent sunshine, [Texas ranks first in the nation in solar resource potential](#).

⁸ [ERCOT GIS Report, June 2016](#).

⁹ US Solar Market Insight Report, Q2 2016, GTM Research and SEIA, June 2016.

¹⁰ Ibid.

¹¹ Ibid.

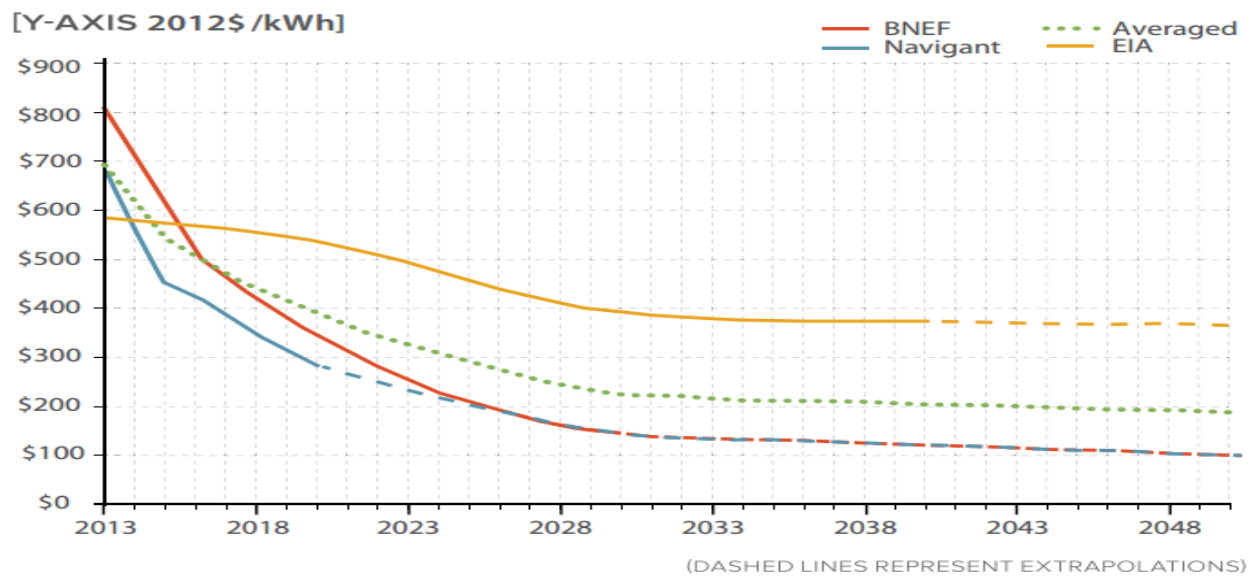


Figure 4. Electric Energy Storage Cost Projections¹²

Like solar, energy storage applications range from the very small to the very large. Small applications include the batteries used to power mobile phones and other smart electronics. Electric and hybrid vehicles have been commercially available for years, and are becoming more efficient and less expensive every year. Electric vehicles may soon become integral parts of residential and commercial building energy systems, not only to recharge batteries when vehicles are not in use but also to discharge energy to the building during grid emergencies or at times when grid-supplied electricity is more expensive.

Energy storage systems for residential and commercial buildings are becoming widely deployed in parts of the world where the services they provide are cost-effective, and electricity consumers and utility companies in the United States are working to understand the value streams that storage technologies may provide. Customer-sited, grid-connected storage may provide value to electric customers by storing energy when it is inexpensive and discharging it when it is more expensive, by reducing utility demand charges,¹³ and by ensuring reliability of electricity supply for critical operations during storms or other outages.

Utilities may benefit from customer-sited or utility-scale storage systems that provide voltage support, regulation or load curtailment services during critical periods.

“
Storage provides value by storing energy when it is inexpensive and discharging it when it is more expensive, by reducing utility demand charges, and by ensuring reliability of electricity supply for critical operations during storms or other outages.
 ”

¹² From [Distributed Solar PV for Electricity System Resiliency](#), NREL.

¹³ Demand charges typically comprise a significant portion of commercial and industrial customers’ electric bills, but do not often apply to residential customers.

The increasing integration of variable renewable energy generation resources, such as solar and wind, onto the electric grid has also resulted in greater interest in electric storage options to smooth out generation from these resources over time.

Each of these storage applications represents a potential value stream, but not all value streams currently can be captured in Texas' electric marketplace. New market structures will need to be created so that investors in storage technologies are able to realize a return on their investments.

In discussing the benefits that electric storage systems provide, two terms are commonly used and are worth defining because they relate to the benefit cost analysis model proposed in this report:

- **Reliability** can be defined as the ability of the power system to deliver electricity in the quantity and with the quality demanded by users. Reliability means that lights are always on in a consistent manner. For our purposes, reliability benefits generally accrue to an electric utility rather than to individual customers, and are not valued in the benefit cost model.
- **Resilience** is concerned with the ability of a system to recover and, in some cases, transform from adversity. Resilience approaches emphasize the idea that disruptive events occur regularly and that systems should be designed to bounce back quicker and stronger because the impact was less. The proposed benefit cost model considers the value to local governments of resilience for solar plus storage systems, and Section 2 describes the approach to (and limitations of) quantifying the value of resilience.¹⁴

Typical Solar and Energy Storage System Components

Solar Panels

Solar panels, also called solar modules, are packaged, connected assemblies of solar cells, typically protected by tempered glass in the front, aluminum framing around the sides, and an adhesive vinyl resin back sheet. The assembly is designed to protect the solar cells and circuits from degradation induced by weather (including damage from moisture, sunlight, and heat) over a long lifespan – most modern solar panels are warranted by their manufacturers for 25 to 30 years. Solar panels also have an electrical junction box mounted to the backside, to enable connectivity to other panels and related equipment.

Typical solar panels currently used for residential and commercial buildings measure approximately 2.5-3 x 4-5 feet and are capable of generating 250-325 Watts of direct current (DC) electricity under full sun.

Panels are arranged in series into strings, electrical circuits designed to output desired voltage and current requirements of selected inverters. A solar electric system may consist of many strings comprising a larger array. Larger and more powerful panels may be used in utility-scale solar applications.

¹⁴ These definitions are adapted from [What's the Difference between Reliability and Resilience?](#) by Aaron Clark-Ginsberg, Stanford University, for the Industrial Control Systems Cyber Emergency Response Team (ICS-CERT) of the US Department of Homeland Security.



Figure 5. Solar Panels at the National Renewable Energy Laboratory's South Table Mountain Campus¹⁵

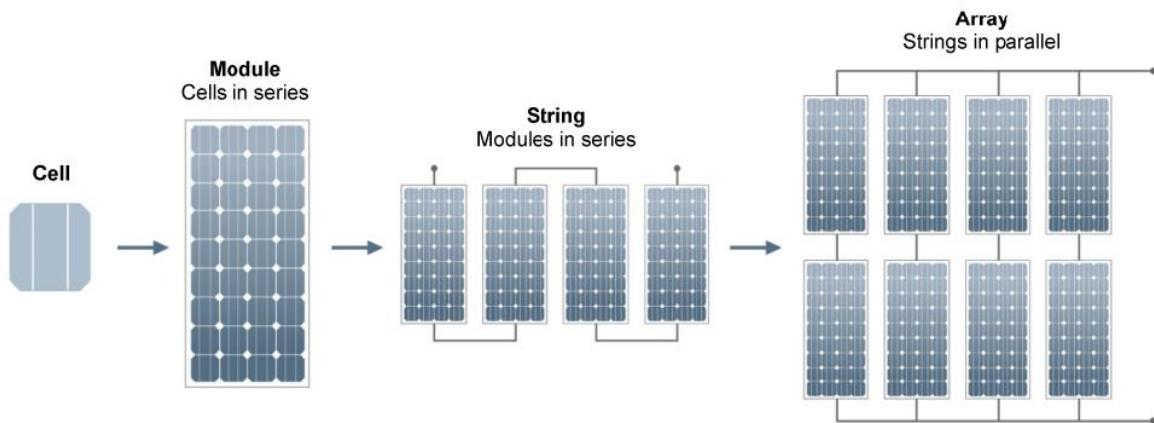


Figure 6. Solar Cells, Modules, Strings, and Arrays¹⁶

¹⁵ Photo courtesy of NREL.

¹⁶ Diagram from [Photovoltaic Systems](#).

Most solar panels are sold as direct current (DC) devices, which are connected together to provide input voltages and currents required by inverters. Some solar panels, however, integrate tiny inverters within the electrical junction box mounted to the backside, and may be sold as alternating current (AC) panels. AC panels are likely to be most useful on installations where shading, tilt, or orientation varies significantly from panel to panel, or where there is insufficient space available to mount inverters.

The most common commercially available solar panels today utilize mono- or poly-crystalline silicon, or thin film.

- **Mono- (or Single-) crystalline** silicon technologies comprise the most efficient types of solar panels commercially available today, meaning they convert available sunlight into electricity at the highest rates. They tend to be more expensive than other types of solar technologies, but require less area to produce the same amount of power. Solar panels utilizing mono-crystalline cells can often be identified by their square-ish cell shape, a result of how the silicon crystal is grown.
- **Poly- (or Multi-) crystalline** cells and panels tend to be less expensive but also slightly less efficient than mono-crystalline. Individual cells are square and can fill up most of the area within a solar panel, making up for some of their efficiency loss with extra surface area to collect sunlight.
- **Thin film or amorphous** silicon technologies are essentially sprayed or printed onto glass or flexible substrates, so they can be used in a variety of ways, for example integrated into roofing materials or landfill covers. Because they tend to be less efficient than other technologies, they require more surface area to produce an equivalent amount of energy. That's why thin films tend to be deployed where available space is abundant and inexpensive, like big solar farms.

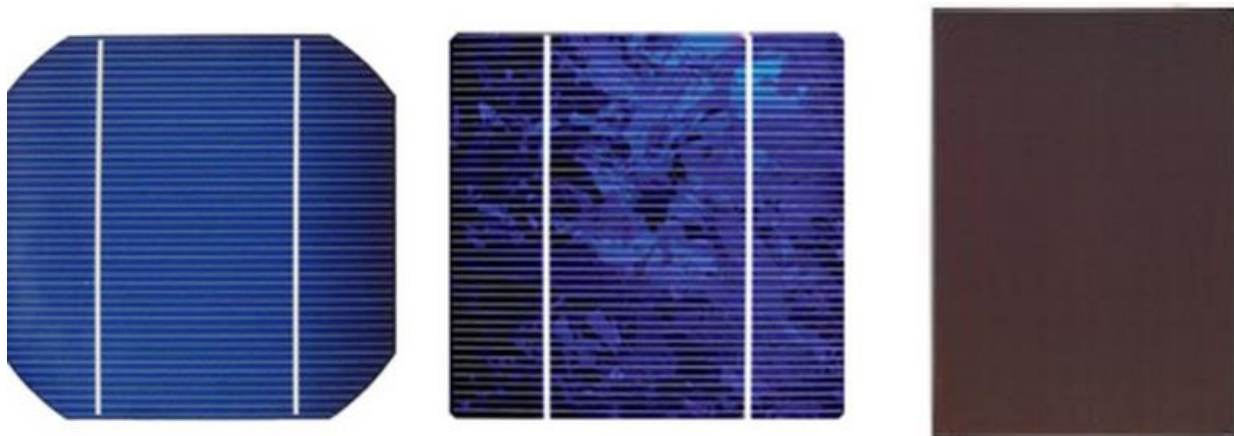


Figure 7. Mono-crystalline (left), Poly-crystalline (center), and Thin Film (right) solar cells

Currently available solar panels convert the energy in sunlight into usable electricity at efficiency levels of about 10 to 25 percent.¹⁷ Conversion efficiency is an important consideration when deploying solar in constrained

¹⁷ Individual solar cells in research environments have recently achieved greater than 40 percent efficiency; however these are not commercially available. The National Renewable Energy Laboratories maintains a [timeline of best research-cell](#)

spaces, but generally does not factor greatly in evaluating the benefits and costs of solar. Financial analyses are driven by cost per annual kilowatt-hours produced, rather than annual kilowatt-hours produced per area covered by the solar energy system.

Inverters

Solar inverters convert the direct current (DC) electricity produced by solar panels into alternating current (AC) electricity matched to the frequency provided by the electric utility system or for off-grid use. In other words, inverters are responsible for making solar energy compatible with lights, appliances, and other common electric loads.

- **Grid-tied inverters** are designed to meet rigorous safety and compatibility requirements associated with supplementing electricity supplied by an electric utility. Most grid-tied inverters manage the interface between a solar array and a building's electrical system, and are only active when grid power is available. Some grid-tied inverters also coordinate charging and discharging batteries and the delivery of power to selected loads during outages. Grid-tied inverter designs usually fall within one of the following categories:
 - **String inverters** are designed to handle the output of one to three module strings, and are most common on residential and commercial solar installations up to 100 kWdc.
 - **Central inverters** are larger, often pad-mounted, devices that are used in larger commercial and utility-scale solar applications.
 - **Micro-inverters** mount directly to individual (or sometimes pairs of) solar panels to convert DC to AC electricity at the panel level. Micro-inverters may be integrated into the solar panel design by the manufacturer, resulting in an AC module, or sold separately and attached to modules by the installer.
 - **DC optimizer** designs split the inverter function into two parts, with DC optimizers mounted at the solar panel (or pair of solar panels) level to optimize panel-by-panel performance, and a separate string or central inverter to convert DC to AC power. Like micro-inverters, DC optimizers may be integrated into solar panels by the manufacturer or sold separately and attached to modules by the installer.
- **Stand-alone inverters** are used in isolated systems that incorporate battery storage. They typically handle battery charging and management, as well as supplying AC power as needed to a load center.

Common commercially-available inverters convert available DC energy supplied by solar panels to AC energy at efficiencies ranging from about 90 to 98 percent, with most in the range of 95 to 97 percent.¹⁸

efficiencies. Overall system efficiency is diminished when connecting cells together into panels, panels into arrays, in the conversion of DC to AC power, and due to environmental factors such as shading and soiling of modules, ambient temperatures (higher temperatures tend to reduce solar output), and degradation of system components over time.

¹⁸ Inverter efficiency ratings are available on specification sheets provided by manufacturers. These are typically reported as peak efficiency ratings, achieved under ideal operating conditions. The California Energy Commission posts a weighted

Mounting Hardware

Solar energy systems are most often mounted on rooftops or on ground-based structures, such as parking shade structures. Professionally engineered mounting solutions are available for nearly every roof, from mounting on residential pitched asphalt shingles or Spanish tiles, to commercial standing seam metal or flat poly vinyl chloride (PVC), thermoplastic overlay (TPO), or rubber surfaces. Ground mounted racking solutions are available for every size installation, from small top-of-pole systems to parking shade structures to desert-mounted utility-scale arrays. Mounting systems are designed to withstand wind and snow loading to meet local requirements, and most are integral to the electrical grounding of the solar energy system.

System Data and Management Software

Most modern inverters, including micro-inverters, have certain data monitoring and control capabilities built in. These and other devices can be configured to download operating data to a computer for analysis, or to upload data to a website for anytime, including real-time, access to operating information about the solar energy system. Systems incorporating battery storage may offer deeper levels of control, with user-defined set points determining when to charge and discharge batteries.

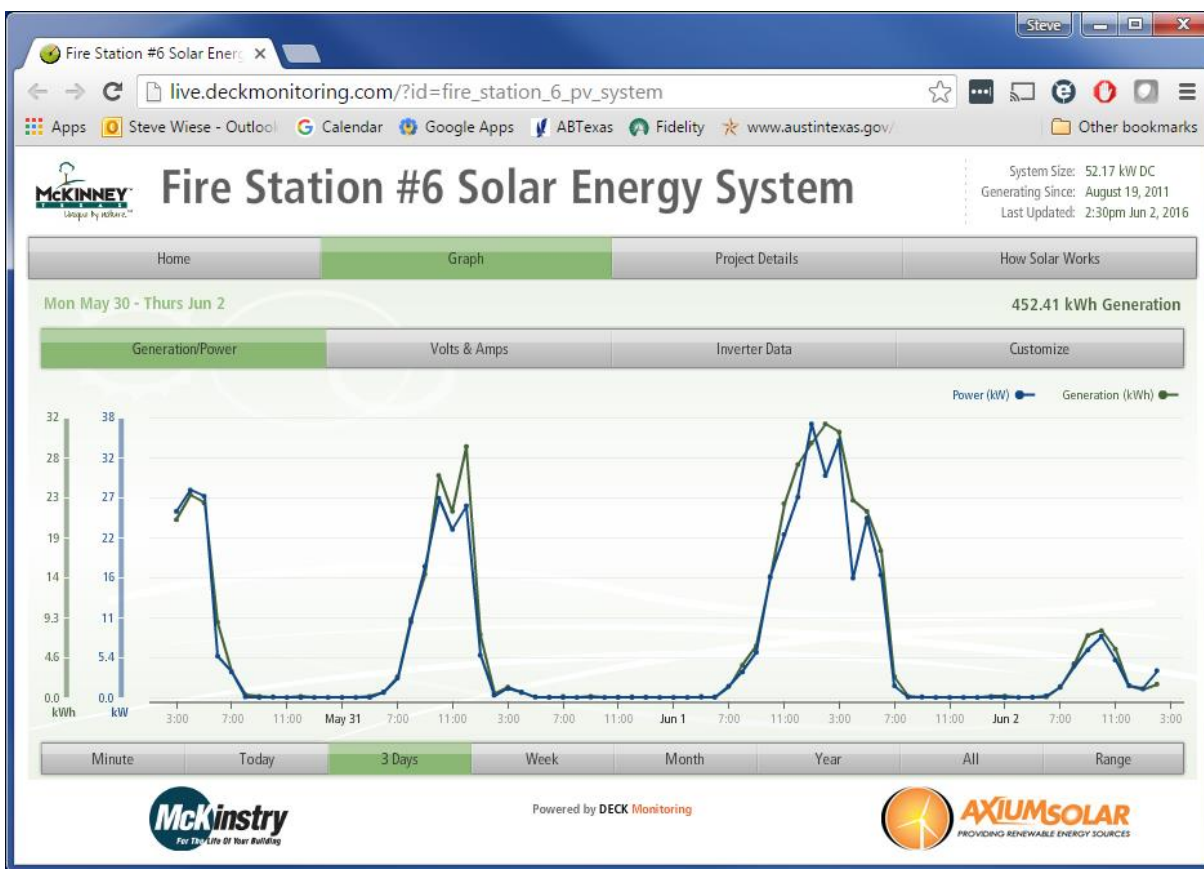


Figure 8. McKinstry Fire Station #6's Web-Based Solar Energy System Monitoring Application.¹⁹

efficiency, designed to estimate the average efficiency of an inverter over typical operating conditions, for most common inverter types. These ratings are available at the [Go Solar California website](#).

¹⁹ Available from [Deck Monitoring's online portal](#).

Battery-Based Energy Storage

Not all solar energy systems integrate battery storage capabilities, but those that do play a major role in providing emergency power in the aftermath of grid outages and natural disasters. Currently, the most common practice for protecting critical facilities or assets during grid outages is to use emergency back-up generators. Generators are typically fueled by diesel and are started up at least monthly for maintenance purposes. When grid power is unavailable to a site, the back-up generators are used to provide power until the grid is running again. This process regularly consumes fuel and creates emissions, and procurement of back-up generators generally does not prioritize fuel efficiency because of their limited run times.

Solar, when combined with battery storage and emergency back-up generators, is able to survive much longer grid outages than generators alone and can extend the generator's diesel fuel supply. A recent NREL study determined that when a generator was supplemented with solar and storage, the probability of survival through an outage increased from 5 days to 12 days. Their results indicate that energy supply is more secure when renewable energy and energy storage technologies are included in the system.²⁰

In California, researchers recently investigated how combinations of solar and energy storage might reduce the electric bills of residents in low income housing. Their report concluded that properly-sized solar and energy storage systems can virtually eliminate electric bills for some owners of affordable rental housing, and can do so more cost-effectively than solar alone. For example, the report noted that the addition of an \$112,100 battery storage system to a \$385,000 solar installation increased savings from \$15,000 per year to \$27,900, an 85% increase in savings for only a 29% increase in cost.²¹

Batteries are most often stored in ventilated enclosures. Most commonly used in hybrid power applications are deep cycle flooded lead acid batteries, which require regular maintenance to maintain electrolyte levels and ventilation to avoid buildup of gases. Newer lithium ion batteries are currently being developed for use with solar and hybrid power systems as well, and still other battery chemistries show promise for providing many sources of value on the electric grid to end-use electric consumers and electric utilities.

Critical Load Subpanel

A critical load subpanel is an electrical distribution circuit that is designed to provide power from a solar or solar plus storage system in the event of a power outage. Depending on the scale of the solar and storage system, it might consist of a single 120V standard outlet to power a laptop or other small load, or any larger connected loads deemed critical by the user. In an emergency services setting, a critical load subpanel might be configured to supply power during blackouts or brownouts to a 911 call center or to hospital refrigerators that maintain drugs or blood at desired temperatures.

²⁰ See [How Solar PV Can Support Disaster Resiliency](#), NREL.

²¹ [Closing the Clean Energy Divide](#), by the California Housing Partnership, Center for Sustainable Energy and Clean Energy Group.

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Energy supplies are more secure when renewable energy and energy storage technologies are included in the system.

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Balance of System (BOS)

Balance of system is a term used to capture other parts of solar energy systems, including wiring and conduit, fuses and switches, and any other parts necessary to ensure safe and reliable system operation.

Common Deal Structures for Solar and Storage Systems

Local governments wishing to procure solar and storage systems to serve public facilities may be overwhelmed by the proliferation of purchase options that may be possible. This section aims to describe some of these options from a high level, and to narrow the discussion to those that are most common for public entities in Texas. We begin with three critical questions:

- Who owns the solar/storage asset once construction is complete?
- How will capital costs be paid or financed?
- Who bears the risks associated with system performance over time?

Ownership

Solar and storage systems may either be directly owned by the local government, or owned by a third party.

Direct Ownership

Under direct ownership, the local government contracts for the design and installation of equipment. The equipment is typically sited at and provides electricity to a public facility, such as a library, school, fire station or water treatment plant. Deployed in combination with utility incentives and/or other grants, direct ownership has been the most common deal structure to date for public entities in Texas seeking to supplement a building's or other facility's energy supply with a solar energy system.²²

The procurement process under the direct ownership model is similar to that for any other public construction or renovation. Capital may come from a combination of cash on hand plus available utility incentives or grants, and may be financed by the local government via bonds or other applicable financing mechanisms.

An advantage of direct ownership is that it generally conforms to established procurement and maintenance practices. Further, systems procured in this manner typically maintain eligibility for certain public grants or other incentives earmarked for public agencies. A disadvantage is that public entities are not eligible for federal tax credits or commercial depreciation allowances, both of which may increase costs relative to third party-owned systems.

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An advantage of direct ownership is that it conforms to established procurement and maintenance practices.
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Public entities may also have concerns about maintaining unfamiliar equipment or performance risks. However, it should be noted that maintenance costs tend to be very small for most solar energy systems, and maintenance

²² Many Texas public investments in solar were spurred by federal funds made available through the American Recovery and Reinvestment Act of 2009 (ARRA) and distributed to local governments by the Texas State Energy Conservation Office (SECO) from 2010 to 2012. To date, third party ownership models have tended to be more prevalent in cases where a municipal utility or rural electric cooperative invests in solar generation as a supply option for resale to its retail customers, such as with community solar programs.

and performance risks are typically easy and inexpensive to mitigate. Most directly purchased systems come with basic warranties from the installation contractor and equipment manufacturers, and additional performance guarantees are commonly available for purchase. Public purchasers may also avail themselves of information resources, such as those available at www.GoSolarTexas.org, to increase their familiarity with typical maintenance tasks and costs.

Third Party Ownership

Third party ownership refers to contract structures that entitle the customer to the energy services and savings provided by solar or storage equipment without owning the equipment outright. These models evolved in part to enable customers who were ineligible for federal tax credits and accelerated depreciation allowances – such as public entities – to leverage those incentives via the eligible third party owner. The owner may then pass savings on to the customer in the form of an equipment lease or power purchase agreement (PPA).

In a lease, the customer (lessee) agrees to pay a fixed monthly fee in exchange for the services and savings provided by the leased equipment. Typically leases will contain provisions that require the lessor to maintain the system and for the equipment to perform at certain levels throughout the contract term.

A PPA is similar, but instead of a fixed payment the purchaser pays for energy produced (and/or other services provided) by the third party owned system.

Many third party ownership deal structures have buyout provisions that enable the purchaser to take ownership of the system, for a defined price, after a certain period of time.

Aside from the advantages associated with federal tax credits and depreciation, some purchasers value predictability of payments (in the case of leases), the elimination of a budget line item for system maintenance, as well as a perceived reduction in risk that comes when a separate entity is responsible for operating and maintaining equipment that may be unfamiliar to the purchaser. There may also be advantages or disadvantages associated with how a lease or PPA is recognized on the customer's financial statements.

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Third party ownership may offer cost advantages as well as greater predictability of costs and benefits.
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Financing

When local governments directly purchase solar or solar plus storage systems, they may pay for the capital costs either through cash on hand or may finance the purchase via bonds or other applicable methods. Financing flattens cash flows over the life of a project, reducing upfront outflows while increasing outflows over the financing term, and typically increases overall project costs. Financing can greatly affect the direct financial benefit and cost metrics. The financial pro forma models developed by Frontier include basic financing functionality which can be customized to meet specific needs.

In Texas, SECO's LoanSTAR revolving loan program finances energy-related cost-reduction retrofits for state, public school district, public college, public university, and tax-district supported public hospital facilities. Low

interest rate loans are provided to assist borrowers in financing their energy-related cost-reduction efforts. Applicants repay the loans through the stream of energy cost savings realized from the projects.²³ Third party owners may finance their purchase of solar and storage equipment, but the financial pro forma model does not account for this financing since it is not directly apparent to the local government considering the investment.

Performance Risk

Local government officials may be concerned about the long term performance of solar and storage investments. Performance risk can be mitigated or managed directly by local governments or indirectly through intermediaries. Typically, when a local government directly owns a solar or storage system, the system and its components will be covered by some form of warranty protection from the designer, installer, or equipment manufacturer. Additionally, local governments may require bidders to provide a performance guarantee over some term, often the estimated useful life of the system. Performance guarantees are usually expressed in terms of expected energy generation per year, with some allotment for annual variations in weather and expected degradation of solar panel efficiency.²⁴ They can be required by local governments regardless of whether the system is directly- or third party-owned.

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Performance risks can be mitigated via guarantees provided by the installer or third party owner.
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Additional Comments on Deal Structures

There are many additional emerging deal structures and financing mechanisms that local governments may wish to consider, but that are not fully addressed in this report. These include:

- **Group purchasing.** Public entities may reap benefits by buying solar and storage in bulk by combining the purchase of several systems into a single contract, by coordinating public purchases with other private purchases in a community, or by engaging in group purchasing with additional public entities. Coordinated group purchase opportunities can reduce contractors’ material, design and labor costs, as well as soft costs that would otherwise be dedicated toward marketing and sales; these reduced costs may be passed on to the purchaser engaged in a group purchasing strategy.
- **PACE financing.** PACE stands for Property Assessed Clean Energy, and is a financing tool that enables customers to finance a solar or other energy efficiency purchase and pay it back via a voluntary property assessment. This mechanism is designed to encourage investments in clean energy by reducing risks, lowering financing costs, enabling the efficient transfer of debt to new property owners when sold, and reducing barriers to obtaining credit by associating the debt owed with the property itself instead of the owner. In Texas PACE financing is relatively new and is becoming available in a number of regions, but it is only available to commercial buildings that pay property tax, and not to government agencies.²⁵

²³ [LoanSTAR Revolving Loan program](#), SECO.

²⁴ All solar panels degrade slightly over time. The financial pro forma model included with this report assume a default annual degradation rate of 0.5%, consistent with the average degradation rates for single- and multi-crystalline Silicon based solar panels. Thin film solar panels tend to have higher degradation rates, averaging about 1% annually. See, for example, NREL, [Photovoltaic Degradation Rates — An Analytical Review](#).

²⁵ [Keeping PACE in Texas](#).

- **Community solar.** Community solar typically refers to larger solar projects that are divided into shares which are sold to individual buyers. These shares entitle the buyers to the energy produced by their share of the larger project. Community solar transactions must be mediated by an electric utility or retailer if the energy is to be credited on the customer's electric bill. Recent community solar projects have made use of available underutilized public lands, public housing or public school rooftops, as sites for community solar arrays. The US Department of Energy provides [information about community and shared solar models](#). In San Antonio, [CPS Energy's SimplySolar program](#) offers electricity bill credits – about \$25 per solar panel annually – to private home and business owners who volunteer their rooftops to house community solar arrays.

2. Benefit-Cost Modeling Approach

A Framework for Assessing Benefits and Costs

Costs of solar deployments tend to be fairly straightforward. For solar applications purchased directly by local governments, costs include capital costs and operating expenses over the lifetime of the system, and may or may not include costs associated with financing. Grants or utility incentives may reduce these costs. As an alternative to directly purchasing solar, local governments may contract with a third party to own and operate a solar energy system, with the benefits of that system delivered to the local government. These “third party ownership” models typically take the form of a lease, where the solar asset is leased to the local government, or a power purchase agreement (PPA), in which the local government contracts for the energy actually produced and delivered to local facilities. In these cases, costs are expensed in a manner similar to operating expenses. A purchase option may be included at the end of the lease or PPA term.

Benefits of solar deployments may be more complicated. Some benefits lend themselves well to quantification via financial pro forma analysis. For example, annual electricity bill savings may be estimated by careful evaluation of expected system performance and current electric rates. These savings may be extended over the lifetime of a proposed solar project by making a few assumptions about future production and utility rates.

Other benefits may be more difficult to quantify, or may not accrue in a direct financial sense to the local government, even as they advance clearly stated local government objectives.

To accommodate the diversity of benefits and costs solar projects present to local governments, we propose a method for benefit-cost analysis that addresses both direct financial benefits and costs, as well as additional community impacts.

Direct Financial Benefits and Costs

Direct financial benefits and costs are defined as those which accrue directly to the local government’s budget, balance sheet and cash flow statements. These are benefits and costs that are internalized by the entity considering the solar investment. Most commonly, these include capital costs, operating expenses, and electric utility bill savings, but may sometimes include other benefits that can be internalized by the local government. For example, if a local government installed solar-covered parking spaces at an airport or other facility, and these covered spaces commanded a premium fee over non-covered parking spaces, the incremental parking revenue generated by the solar-covered spaces could be modeled as a direct financial benefit. In another case, if a solar installation on privately-owned underutilized land enabled that land to be put to productive use and increased its taxable value, the increased tax revenue could be modeled as a direct financial benefit. The list below summarizes the direct financial benefits and costs modeled by the financial pro forma developed for this project. Each item is further detailed in the sections that follow.

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Direct financial benefits and costs are those which accrue to the local government’s financial statements.

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Direct Financial Benefits

- Electric bill savings
 - Avoided energy inflows
 - Value of outflows
 - Avoided demand charges
 - Secondary rate effects
- Property tax revenue
- Value of shade/shelter
- Renewable energy credits (RECs)
- Time of use arbitrage
- Resiliency

Direct Financial Costs

- Capital costs
- Operating costs
 - Scheduled maintenance
 - Unscheduled maintenance
 - Other operating costs
- Financing costs

Electric Bill Savings

Solar installations have immediate effects on electricity costs via offset of energy and capacity provided by electricity retailers. In a typical configuration, a solar energy installation will inject electric energy into a building or other metered load on the customer's side of the utility electric meter. Depending on the time of day and the electric loads present in the building, the solar electricity produced can either:

- Reduce the need for electricity that would otherwise flow to the customer through the meter provided by the electric utility ("avoided energy inflows"); or,
- Be exported to the grid through the electric meter ("outflows").

Avoided energy inflows and outflows to the grid may have different values in financial analysis, but in sum they tend to comprise the vast majority of financial benefits created by solar investments.

Estimating how much solar energy is likely to be produced by a given solar energy installation is fairly straightforward with the right modeling tools. An accurate estimate may be made using the online [PVWatts® calculator](#) provided by the National Renewable Energy Laboratory (NREL) and available at. Key inputs to the tool include:

- The location of the proposed system
- The capacity of the proposed array, in DC kilowatts
- The tilt and orientation (azimuth) of the solar panels in the array²⁶

Estimating the proportions of annual solar generation that are likely to avoid energy inflows versus outflow back to the grid is more complex, and requires consideration of the building and solar hourly load shapes over a year. Ideally, one can generate both the building and solar hourly load shapes using the same underlying set of typical meteorological year (TMY) weather data – sets of weather data derived for a specific location but generated from

²⁶ Additional inputs may be entered to refine the estimate provided.

a data bank much longer than one year in duration. Alternative methods can be explored by energy managers or others familiar with building loads and operations.

Avoided Energy Inflows

At times when a solar energy system is producing energy, but the building or load it serves is consuming more energy than is being produced, there will be a net inflow of energy through the utility meter to the customer. The inflow of energy from the utility is reduced by the amount of solar energy produced, and can be valued at the retail electricity rate shown on the customer’s electric bill. This rate is typically expressed in dollars per kilowatt-hour (kWh), and may consist of several different components that should be summed to represent the savings achieved by each kilowatt-hour of solar energy produced.

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Avoided energy purchases from the utility comprise the largest share of financial benefits created by solar.
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The value of avoided energy inflows in future years may be estimated by applying a retail energy price escalation rate (these are typically assumed at between 1 and 3 percent). The figure below shows the commercial retail electricity price history in Texas going back to 1990, with a linear trend line starting around 6.3 cents per kilowatt-hour and increasing to about 9.4 cents per kilowatt-hour in 2016, suggesting an average annual escalation rate of about 1.5 percent. While the rate of change of actual retail energy prices varies considerably over the short term, these data can be used as a basis for estimating the long term trend applicable to many local government facilities.

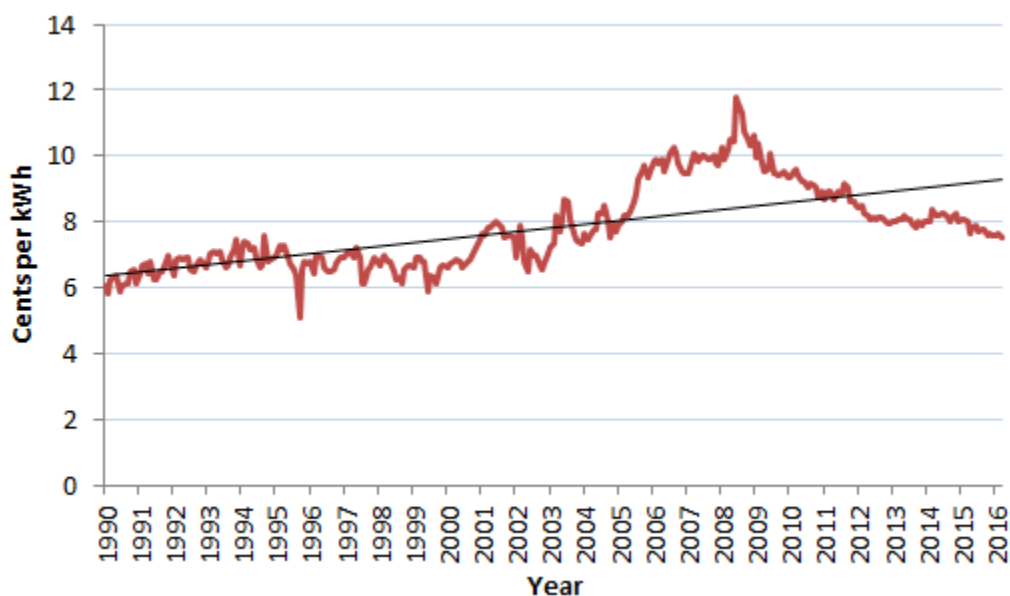


Figure 9. Texas Commercial Retail Electricity Prices (red) and Linear Trend (black), 1990-2016²⁷

²⁷ Derived from “[Retail sales of electricity to ultimate customers, monthly, by sector, by state,](#)” Energy Information Administration, US Department of Energy.

Outflows

At times when the solar installation is producing energy in excess of the building load, the excess energy is exported through the utility meter and may be recorded as outflows. In Texas, the value of outflows depends on where the solar installation is located, and on the type of electric utility that serves customers in that location.

In areas of Texas served by retail electric competition (investor-owned utilities operating inside the Electric Reliability Council of Texas, ERCOT, footprint), customers may be able to be credited for outflows by the customer's selected retail electric company; however, that company is not required to purchase this power. Some companies that do purchase solar outflows may require that the customer also subscribe to a specific retail offer. Other companies may allow the purchase and sales offers to be chosen independently by the customer. Electric customers in competitive choice areas should contact their retail electric provider to see if crediting for outflows is offered by the retailer. Local solar installation companies also can advise prospective solar customers about which retailers offer the best options for customers with solar.

Investor-owned utilities serving areas without retail choice are required to credit outflows at the utility's "avoided cost," which is the price the utility would have paid for an equivalent amount of conventionally generated electricity. Avoided cost is always less than the retail cost as defined for avoided energy inflows, and typically comprises about one-third to one-half of retail costs.

Most areas of Texas without electric competition are served by municipal utilities or rural electric cooperatives. Customers in these regions should contact their utility or cooperative directly with questions about being credited for solar outflows. Some offer credit for outflows at the retail rate via net metering, others credit outflows at their avoided costs or other values, and still others offer no credits for solar outflows.

As energy storage options become more economically viable in Texas, the differential values attributed to energy inflows and outflows becomes less important to financial analysis, since it enables excess solar energy to be stored by the customer and discharged into the building to offset inflows. Such strategies may reduce or eliminate solar outflows, enabling all solar production to be valued at the avoided energy inflow rate.

Avoided Capacity

Capacity or demand charges are common on commercial and industrial electric utility accounts. With capacity charges, a portion of the customer's monthly bill is determined based upon the maximum amount of capacity drawn by the customer at any time as recorded by the customer's electric meter. A solar installation may or may not reduce a capacity charge in any given billing cycle: its value is dependent on the overlap between building energy loads and actual solar energy production.

With sufficient building energy use data, that overlap can be modeled to estimate reductions in peak demand attributable to a new solar installation. On average, during summer months common commercial solar energy systems can be expected

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With sufficient building energy use data, solar's contribution to reducing demand charges during a billing cycle can be reasonably estimated.

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to reduce *the utility's* peak demand at 36 to 49 percent of their DC rated capacity.²⁸ The potential contribution of a solar energy system to reducing *a customer's peak demand* during a billing cycle is more difficult to predict, but reasonable predictions may be made with access to the customer's 15-minute or hourly energy consumption data, if such data is available.

Utility demand charge policies can complicate solar's ability to reliably capture demand charge reductions. One example is the practice of "ratcheting," in which a single month's peak demand is extended to future months even if measured peak demand later decreases.

Many solar installation companies ignore potential demand charge impacts in their own financial analysis provided to prospective customers because of the complexity of the analysis required, the lack of available load data, and/or the uncertainty around whether avoided capacity savings will be realized. If building loads can be reliably modeled, however, demand charge savings attributable to a potential solar installation may be substantial and should not be ignored.

Secondary Rate Effects

In a competitive retail electricity market, secondary effects on energy pricing are possible as well. Savvy energy consumers and retailers may use solar as a load shaping tool that can reduce the retailers' costs of energy procurement and provide the customer with negotiating leverage to obtain more advantageous energy supply terms. Such benefits are uncommon, but may be explored.

Property Tax Revenue

The value of solar improvements made to private property, where the solar energy produced is "primarily for the production and distribution... of energy for on-site use, or devices used to store that energy," is exempt from property taxation in Texas. The [Texas property tax exemption](#) applies to commercial, industrial, and residential properties.

Solar deployed on otherwise undeveloped private land for commercial uses can result in an increased assessment of improved value and local property tax collections. These primarily include applications where the proposed solar development is intended to serve off-property loads; for example, where a solar developer intends to sell the generated electricity to the local government for use at its facilities located throughout the city, or to a municipal utility.

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Solar deployed on undeveloped private land for commercial uses can increase local property tax collections.
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Because the capital costs of solar are relatively high and the payback period is relatively long, private solar developers seeking commercial uses often negotiate with local governments for reduced improvement valuations, or reduced assessments, over a defined period. Local governments who want to see the land improved sometimes see more value in offering a reduced improvement valuation than in having

²⁸ The cited range of 36 to 49 percent represents deemed summer capacity savings factors for commercial photovoltaic arrays oriented due south at tilts between 0 and 15 degrees, according to the Texas Technical Reference Manual (TRM) version 4.0 (currently unpublished draft), chapter on nonresidential solar photovoltaic measures, authored by Frontier Associates. Once published, Texas TRM version 4.0 will be available at the [Texas Energy Efficiency website](#). The TRM is used by electric utilities in Texas to quantify savings attributable to various energy efficiency measures.

no improvement at all. The [Texas Economic Development Act](#) authorizes Texas school districts to consider applications for limitations on the appraised value of qualifying investments that reduce the taxpayer's school district tax obligation.

In any case, the property tax revenue benefit is calculated as the difference between current tax revenue and projected tax revenue after the project is installed.

Value of Shade/Shelter

Shade and shelter provided by solar energy systems may produce direct financial benefits in several situations, each with a unique valuation method:

- **Solar covered parking spaces** may command a higher fee than non-shaded spaces. For example, some covered spaces at the Dallas Fort Worth International Airport currently command a two dollar per day premium over non-covered spaces.²⁹ Multiplying this premium by the number of covered spaces and the anticipated utilization rate would yield a direct financial benefit that can be modeled.
- **Solar shade structures** at public parks or other outdoor spaces may yield electric bill savings as well as shade and shelter. The value of shade and shelter may be approximated by the cost of alternative, non-solar, shading structures that otherwise would have been considered for the space. This alternative cost can be input as a benefit in the financial pro forma analysis, in effect isolating the separate cost of shade/shelter from the cost of solar.
- **Certain solar installations on building rooftops or window awnings** may provide shade to the window or roof while still allowing sufficient airflow underneath to keep the roof cool. This in turn can reduce the energy required to cool the building, especially during summer peak utility rate periods. Building simulation software may be used to model the effects of roof and window shading to yield energy efficiency savings.

Renewable Energy Credits (RECs)

Renewable energy credits (RECs) are tradeable commodities that represent that a unit of electric energy was generated from a renewable energy resource. RECs are earned by owners of renewable energy generators, and may be sold to buyers who seek to comply with regulatory requirements or participate in voluntary markets.

- In compliance markets, electric companies are required by law to source a defined percentage or amount of energy from renewable resources, and to demonstrate compliance by holding and retiring RECs.
- In voluntary markets, customers or utilities elect to use renewable energy for their own reasons, and RECs provide a convenient and verifiable means of demonstrating that their purchases are indeed comprised of energy generated from renewable resources.

Public entities do not often sell the RECs associated with solar generation because they typically desire to retain the right to claim environmental benefits associated with that generation. Once RECs are sold to another entity, energy generated from a solar energy system may no longer legally be characterized as "green," "pollution free,"

²⁹ From [Dallas/Fort Worth International Airport, Express Parking Details](#).

or even “solar,” because the rights to claim those attributes belong to the REC purchaser. Thus, REC value typically does not factor into local governments’ evaluation of the direct financial benefits of a solar purchase, but is described here in the interest of comprehensiveness.

More often, REC values represent a starting point for valuing some non-financial benefits associated with solar energy, such as the value of environmental benefits, which are described later.

Energy Storage Benefits

The application of energy storage technologies can provide a variety of benefits to the electric grid, to electricity end-users, and to society as a whole. Benefits that may be quantified financially, and that may be realized by the entity making a financial investment in energy storage, are appropriate to consider when evaluating the direct financial benefits and costs of energy storage. Current examples applicable to energy storage in Texas include time of use arbitrage of energy prices and reduction of electricity demand charges; these comprise the focus of the direct financial analysis examples provided in this report.

- **Time of use arbitrage.** Energy storage systems enable commercial energy customers on time of use rates to purchase and store energy when it is relatively inexpensive, and to discharge stored energy during higher value periods. The potential annual savings generated from daily storage and discharge cycles can be estimated as the product of the energy storage capacity, the round trip efficiency of the storage system, the difference in energy prices between time of use periods, and the number of days in the year.
- **Reduction of demand charges.** Energy storage may also be deployed to reduce a customer’s peak demand or reduce the customer’s load factor.

In some cases, energy storage may enable receipt of incentives for participating in utility- or ERCOT-sponsored load management programs or ancillary services markets. These markets may not be currently compatible with all energy storage technologies, but market designs are being updated to potentially enable participation by customers with energy storage.

- **Participating in load management programs.** Most Texas electric utilities offer incentives for commercial customers to participate in load management programs,³⁰ and ERCOT administers a separate market for similar services.³¹ In exchange for a financial incentive, electricity customers agree to curtail electricity demand by a contracted amount when called upon during defined peak seasons and periods. Customers most often participate in these programs by curtailing defined loads or by maintaining backup generation on site. The availability of electric storage may enable the customer to participate in these programs, increase their curtailable load contract, or maintain normal operations during a curtailment.

³⁰ Information about Texas’ investor owned utilities’ load management programs may be found under the heading Utility Programs at the [Texas Energy Efficiency](#) website.

³¹ ERCOT’s [Emergency Response Service](#) is procured via auction three times annually.

- **Participating in ancillary services markets.** ERCOT also enables market participants to offer frequency regulation services, which may be provided in part by energy storage technologies, within its [ancillary services \(or day-ahead\) market](#).

Others benefits may be difficult or impossible to quantify financially, or may accrue to other entities such as electric utilities, grid operators, or society as a whole. For example, available energy storage may help utilities to integrate greater amounts of variable renewable energy generators onto the system, or may be deployed to reduce loads on transmission or distribution resources at critical times to improve reliability of the grid. These benefits may be considered as additional community impacts of investments in energy storage. For further reading, the [Energy Storage Association](#) maintains a [comprehensive list of the potential benefits](#) associated with energy storage.

Capital Costs

Capital costs of solar projects include all costs associated with engineering and design, permitting, construction materials and labor (including applicable sales taxes and the costs of extended warranties), and commissioning. These costs are typically provided to local governments as bids submitted by contractors. Estimates of capital costs may be obtained from entities that collect data on the costs of large numbers of installed solar energy systems, such as the managers of local utility solar incentive programs,³² or NREL.³³

Capital costs are often reduced by applicable utility incentives and available tax credits. A list of utility incentives for solar, energy storage and other energy efficiency measures is maintained by the North Carolina Clean Energy Center through its [Database of State Incentives for Renewable Energy \(DSIRE\)](#).

Local governments are not able to claim the federal investment tax credit (ITC) directly, but can benefit from this credit when purchasing solar from a third party owner. The ITC, updated most recently by Congress in 2015, offers a tax credit of 30% of the capital costs of solar and other eligible technologies if construction is begun prior to the end of 2019; the credit tapers to 10% by 2022 and future years.³⁴

Operating Costs

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Local governments are not able to claim the federal investment tax credit directly, but can benefit indirectly by purchasing solar from a third party owner.
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³² The [Database of State Incentives for Renewable Energy \(DSIRE\)](#) maintains information on federal, state, and utility incentive programs and contacts, including [data for Texas](#). DSIRE is the most comprehensive source of information on incentives and policies that support renewable energy and energy efficiency in the United States. Established in 1995, DSIRE is operated by the N.C. Clean Energy Technology Center at N.C. State University and is funded by the US Department of Energy.

³³ See [Distributed Generation Renewable Energy Estimate of Costs](#), National Renewable Energy Laboratory. As of February 2016, NREL reported the mean national installed cost of solar photovoltaic (PV) systems with capacity from 10-100 kilowatts DC at \$3.46 per watt DC, though with wide variation in these costs.

³⁴ See DSIRE, [Business Energy Investment Tax Credit \(ITC\)](#).

Operating costs include scheduled and unscheduled maintenance, and other costs. Operating and maintenance costs tend to be very low, relative to capital costs, for most solar projects. Most financial analysis tools assume annual operating and maintenance costs at between 0.5 and 1.0 percent of capital costs.³⁵

Scheduled and unscheduled maintenance

Scheduled maintenance includes the costs of system performance monitoring, annual system checks, module cleaning, and repair and replacement of system components as needed. A key scheduled maintenance event is inverter replacement. Most solar installers assume inverters will need to be replaced every 7-10 years, and so assume inverter replacement costs in their financial projections. Purchasing extended warranties on inverters can lengthen the time between projected inverter replacements.

Unscheduled maintenance costs, by their nature, are harder to predict than scheduled maintenance costs. In financial pro forma analyses, they typically range from zero (least conservative) to the amount assumed for scheduled maintenance (most conservative).

Other operating costs

It is possible, though unlikely, that installation of a solar energy system incurs other costs on a local government, such as increased insurance premiums. Generally, directly-owned solar may incur additional insurance costs directly to the local government, while third party owned solar does not (insurance costs are borne by the third party owner and passed along in the lease or PPA rate). Local government project sponsors should carefully consider other possible direct financial operating costs and account for them if necessary.

Financing Costs

Local governments may purchase solar installations directly, or may borrow money for construction using bonds or other mechanisms. These carry financing costs, such as fees, points, and interest rates which should be considered.

Key Metrics Summarizing Direct Financial Benefits and Costs

Key metrics of direct financial benefits and costs include the following:

- **Net present value (NPV)** – NPV represents the difference between the present value of estimated future cash inflows and outflows associated with a project or investment. A positive NPV indicates that the projected earnings (in present dollars) generated by a project exceed the anticipated costs (also in present dollars). In the NPV calculation, present values of future cash inflows and outflows are

³⁵ NREL's JEDI model assumes annual solar operating and maintenance costs at \$19.93/kWDC installed. This value is adopted in the model financial pro formas for consistency with the jobs and economic development impacts analysis. It works out to about 0.75% of capital costs. It is also consistent with NREL's February 2016 estimate of annual scheduled maintenance costs, in its [Distributed Generation Renewable Energy Estimate of Costs](#) report, at \$19 per kilowatt DC per year for solar photovoltaic (PV) systems with capacity from 10-100 kilowatts DC.

“
Operating and maintenance costs tend to be very low, relative to capital costs, for most solar projects.
”

determined by a discount rate, which typically represents the local government's cost of borrowing or average rate of return on other assets.

- **Internal rate of return (IRR)** – IRR is defined as the annualized effective compound rate of return for a project or investment. It is calculated solely on the basis of project cash flows, without incorporating assumptions about discount rates or inflation, and as such can be used to evaluate the attractiveness of projects or investments. More formally, IRR represents the discount rate at which the net present value of all project cash flows equal zero.
- **Simple payback years** – Simple payback is the length of time (in years) required to recover the cost of an investment or purchase. Shorter paybacks typically represent more desirable investments.
- **Benefit-cost ratio (BCR)** – The BCR is the ratio of the present value of estimated future cash inflows to the estimated value of future cash outflows associated with a proposed project. BCR is closely related to NPV: Projects with positive NPV will have a BCR greater than 1.0, and projects with negative NPV will have a BCR of less than 1.0.

Additional Community Impacts

Additional community impacts are comprised of those which accrue external to local government accounting. They may or may not have quantifiable financial value, but even when they do the financial value does not accrue directly to the local agency considering the solar or storage investment. Some items listed as direct financial benefits are also listed as additional community impacts, and may properly be categorized either way, depending on the unique circumstances of the proposed installation. For example, fee-based solar covered parking spaces may be capable of generating additional revenue over non-covered parking spaces, whereas a solar shade structure at a public park may not generate revenue. Benefits therefore need to be examined on a case by case basis. Potential additional community benefits of solar and storage installations, along with a definition and recommended key metrics for each, are listed below.

Local Jobs and Economic Development

Frontier relied on [NREL's Jobs and Economic Development Impacts \(JEDI\) model](#) to determine benefits related to jobs and local economic development. JEDI estimates the number of jobs and economic impacts to a local area that can reasonably be supported by a power plant, fuel production facility, or other project. Jobs, earnings and output are distributed across three categories: project development and onsite labor impacts, local revenue and supply chain impacts, and induced impacts. JEDI models are used by county and state decision makers, public utility commissions, potential project owners, developers, and others interested in analyzing the economic impacts associated with new or existing power plants, fuel production facilities, or other projects.

JEDI model results are presented in terms of jobs, earnings, and annual output during the construction period and during operating years.

- **Jobs** are the number of jobs created by the project.

“

NREL's JEDI model estimates jobs, earnings, and economic output during the construction and operating periods of power plants.

”

- **Earnings** during the construction period includes money spent on labor (wages and salaries and associated impacts) for people working to develop the project such as environmental technicians and lawyers, and people who construct the project such as road builders and concrete pourers. These impacts encompass jobs that are performed on-site at a given power plant, fuel production facility, or other project, as well as basic project development services and construction management. During operating years these refer to earnings associated with project operations and maintenance.
- **Output** refers to activities that result from income (earnings) spent by workers involved in development and on-site labor and local revenue and supply chain impacts.

Air Emissions Impacts

A number of studies have weighed in on how best to value environmental benefits associated with offsetting fossil fuel-based energy production with renewable energy. Data on emissions reductions can be derived from the [US Environmental Protection Agency's \(EPA\) eGRID database](#), which may be used to estimate offsets of carbon dioxide (CO₂), a greenhouse gas; nitrogen oxides (NO_x), which contribute to smog; and sulfur dioxide (SO₂), which contributes to acid rain. These values can be converted to other equivalencies, such as the number of cars removed from roads, using the [US EPA's Greenhouse Gas Equivalencies Calculator](#).

Resiliency

During grid outages, solar paired with storage can provide emergency power that helps support critical public infrastructure and services. The value of resiliency to a site in this analysis is equal to the estimated costs incurred due to grid interruptions. These costs were derived from the [US Department of Energy's \(DOE\) Interruption Cost Estimator \(ICE\) calculator](#).³⁶ The ICE calculator utilizes utility-specific reliability data reported to the federal government annually, as well as additional default inputs that vary by state. Frontier was able to obtain non-storm and all-event reliability statistics for Texas utilities, and used the most recent five-year average all-event values as inputs into the ICE calculator.

Resiliency values estimated by the ICE calculator represent average interruption costs and/or the benefits associated with reliability improvements in the United States to electric utilities, but these values do not necessarily accrue to individual customers, who may have higher or lower valuation of backup power capabilities, and who may not be able to monetize all of the value created.

Other Community Impacts

As appropriate, additional community impacts from each model solar application are described. These include:

- Reduced risk/exposure to changes in electricity rates
- Increased public awareness
- Silent operation
- Portability
- Shade and shelter

³⁶ Additional information about how the ICE calculator can be used to derive resiliency values for solar plus storage systems may be found in the June 2016 NREL report [New York Solar Smart DG Hub-Resilient Solar Project: Economic and Resiliency Impact of PV and Storage on New York Critical Infrastructure](#).

3. Modeling Solar Applications of Interest

Literally thousands of potential solar applications and contract structures exist. In this report, we closely examine from a benefit-cost analysis perspective five model applications likely to be of interest to local governments and which represent a variety of project types and benefits. For each model application, we have prepared a sample financial pro forma model using Microsoft Excel; these pro formas offer a starting point for project benefit-cost analysis, and may be customized to fit virtually any project. The model applications examined are:

- Simple grid-tied solar
- Solar on landfills or other underutilized sites
- Solar on shading structures
- Grid-tied solar with energy storage
- Mobile solar with energy storage

Each model application is explored more fully in the following sections with a general description, a specific example, and a hypothetical example used in benefit-cost modeling. Hypothetical examples were used in benefit-cost modeling in this report in order to base the modeling on current estimates of project capital costs and electricity prices. These models may be customized for specific projects under consideration by local governments.

Model Application 1. Simple Grid-Tied Solar

General Description

Simple grid-tied solar installations are designed to offset purchased electricity on public properties such as wastewater treatment facilities, city halls or libraries, etc. These systems are by far the most common solar application deployed by public and private entities.

They produce energy when sunlight is present, injecting it into the building and reducing the amount of energy purchased from the retail electric company. Whenever more solar energy is being produced than is consumed within the building, excess energy flows out through the utility meter, and may be (but is not always) credited to the customer at a retail, wholesale, or other value. These systems generally shut down for safety reasons when grid power is not present. In a benefit-cost analysis, economic benefits are primarily comprised of the estimated net present value of offset energy (and, to a lesser extent, capacity); costs are the capital cost of the project plus the estimated net present value of planned and unplanned operation and maintenance (O&M).

Example

An example simple grid-tied solar energy system is the 52 kWdc solar array at Fire Station #6 in McKinney, Texas. The system is estimated to produce about 137,000 kWh of electricity annually, about 50 percent of the Fire Station's annual energy needs.

This project was funded in part by a grant through the Texas State Energy Conservation Office (SECO). It consists of 222 polycrystalline solar modules, rated at 235 watts each, installed on 3 different roof surfaces. The panels are attached to the roof seam utilizing clamps that allow the modules to be attached to the roof without making

penetrations. It utilizes multiple string inverters due to limited space for a large centralized inverter, and includes a web based monitoring system that provides real time energy production data through a standard web browser.



Figure 10. Fire Station #6 in McKinney, Texas³⁷

Inputs Used in Benefit-Cost Modeling

The following table presents key details of the hypothetical model system used for benefit-cost modeling. These inputs do not represent any specific, real-world example of an installed system, but are designed to illustrate a common application likely to be of interest to local governments, with technical specifications, costs, and utility rates that approximate current pricing in Texas at the time of publication (summer 2016). The model is intended to serve as an illustration of current project economics, and forms the basis of a model template financial pro forma which can be customized by local government officials to meet the specific requirements of a locally-considered project.

In this case, we construct a model of a simple, grid-tied solar system that is directly purchased by a local government for use on a city-owned facility. As such, project economics do not benefit from the federal

³⁷ Photo courtesy of [Axium Solar](#).

investment tax credit; however, the net cost is reduced by an incentive provided by the local utility.³⁸ We assume that 10 percent of the energy produced is exported to the grid, but that the local government’s electricity retailer provides a full net metering benefit for such exports (meaning the value of exported energy is equal to the retail price of energy consumed). We also assume that the retail electric contract for the facility is comprised of an energy charge and a separate demand charge, but conservatively assume that solar energy system will reduce demand charges by a small amount (12 percent).

Table 1. Benefit-Cost Model Inputs – Model Application 1 – Simple Grid-Tied Solar

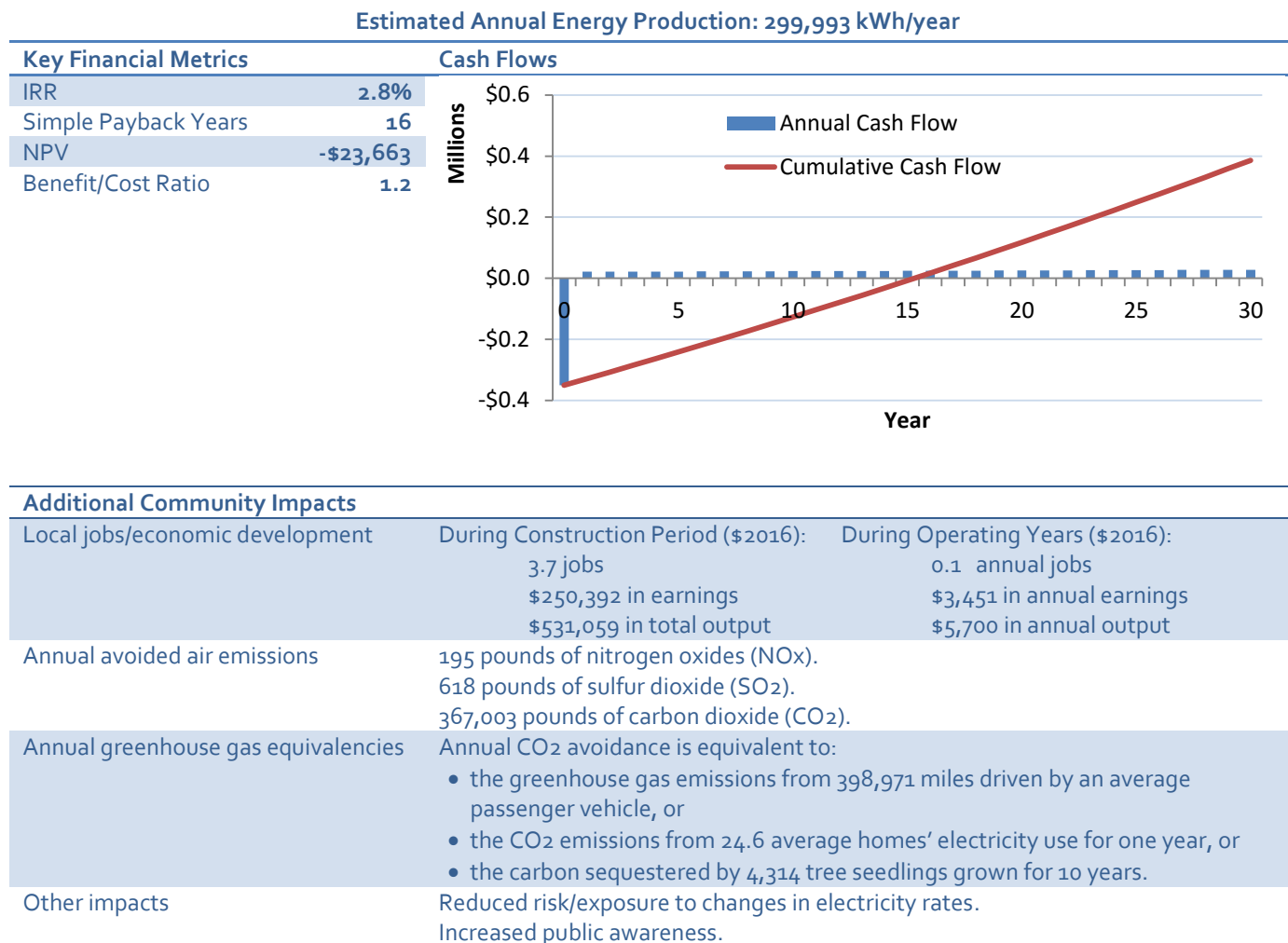
Deal Structure:	Local government owned, directly purchased without financing utilizing available utility incentive. System located in Fort Worth.
PV System Specifications:	200 kWdc rooftop array oriented due south at 20 degree tilt. Estimated life 30 years.
Storage Specifications:	No storage
Installed Cost:	Total installed PV system cost \$500,000 (\$2.50/Wdc). Utility incentive of \$150,000 (\$0.75/Wdc). No federal tax credit or other grants. Net installed cost \$350,000.
Estimated Annual Operating Costs:	\$3,986 in year 1 (per NREL JEDI), escalated at 1.5% per year.
Site Loads and Excess Energy:	PV system sized to serve approximately 50% of facility annual energy requirement. 10% of PV energy is assumed to be exported to the grid. 12% of kWdc PV system rating is assumed to contribute to demand reduction annually.
Site Electric Bill Rates:	Charge for energy inflows: \$0.08 Credit for energy outflows: \$0.08 Demand charge: \$5/kW Annual escalation rate: 1.5%
Direct Financial Costs Modeled:	Capital and operating costs.
Direct Financial Benefits Modeled:	Electric bill energy and demand savings.
Additional Community Impacts:	Local jobs and economic development. Avoided air emissions (CO ₂ , NO _x , SO ₂). Reduced risk/exposure to changes in electricity rates. Increased public awareness.

³⁸ Current (summer 2016) incentives offered by Oncor Electric Distribution, for example, offer approximately \$0.85/Wdc up to 100 kWdc, and \$0.65/Wdc for capacity over 100 kWdc. The \$0.75/Wdc assumed for this 200 kW system is simply the average of these two values.

Benefit Cost Model Results

Benefit cost model outputs, including direct financial benefit cost metrics and additional community impacts, are summarized in the table below.

Table 2. Benefit-Cost Model Outputs – Model Application 1 – Simple Grid-Tied Solar



The financial pro forma template for the simple grid-tied solar application demonstrates best practice financial analysis of perhaps the most common type of solar energy system considered and installed by local governments. While the federal tax credit is not available to the assumed local government purchaser, project economics benefit from an available incentive provided by the local electric utility. The vast majority of benefits to the local government (95%) come from reductions in energy purchased from the electric utility; the rest derives from reductions in demand charges.

Leasing the system from a third party owner could improve project financials, both from reducing net costs and by restructuring the cash flow profile. The financial pro forma template enables the user to model a leased system or to finance the system costs. Like leasing, financing carries the potential to dramatically alter the cash flow profile, reducing or eliminating up-front costs.

Model Application 2. Solar on Landfills or other Underutilized Sites

General Description

Locating solar generation facilities on landfills or other underutilized sites can result in lower overall development costs from inexpensive land prices and tax incentives, and can offer community benefits by converting blighted areas or difficult to develop land into productive assets. These projects vary in their form, depending on what entity owns the land, what entity owns the solar generation facility, and what entity benefits from the energy produced.

With SECO support, the North Central Texas Council of Governments (NCTCOG) has recently mapped datasets provided by the US Environmental Protection Agency (EPA) through its RE-Power America's Land Initiative to identify landfills and other brownfield sites with potential of hosting "utility-scale" solar projects. In addition to producing a solar potential map covering their own members' area (see below), NCTCOG has also produced maps for all of the Councils of Governments in Texas, which may be found at www.GoSolarTexas.org.

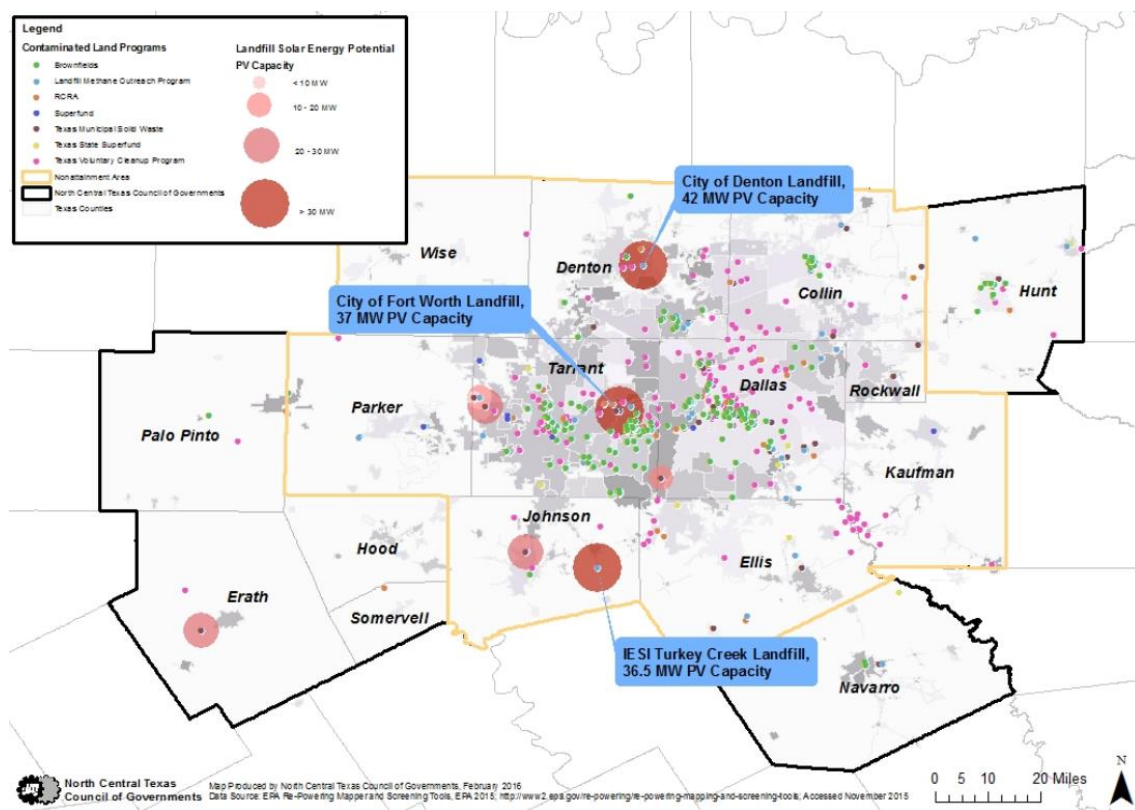


Figure 11. Solar Energy Potential on Underutilized Lands in North Central Texas³⁹

Perhaps the simplest structure for these projects involves public-owned land on or adjacent to a public facility with large and consistent electric loads that may be offset by solar generation, such as a wastewater treatment

³⁹ [North Central Texas Council of Governments](http://www.nctcog.org), using data from the [US EPA's RE-Powering America's Land program](http://www2.epa.gov/re-powering/re-powering-mapping-and-screening-tools) (a full-page version of this map is provided in Appendix C).

plant, convention center, or other facility. The public land and facility owner may contract with a private, third party solar generation facility owner to design, install, maintain and operate a solar electric system at the site. Solar energy produced is injected directly into the public facility, reducing or offsetting electricity that would otherwise be purchased from the electric utility. The public entity contracts with the third party solar owner under a lease or power purchase agreement contract.

This model reduces complexity and cost by involving just two entities, the public land and facility owner and the third party solar generation facility owner. The electricity interconnection supply model is also direct and straightforward – the facility receiving the solar energy produced is on or adjacent to the property which hosts the solar generation facility – and no negotiations with electric utilities or retail electric suppliers are necessary to bring the generated solar energy to the load. The third party solar developer/owner may take advantage of federal tax credits not available to public entities, and the tax savings may be passed on to the public entity in the lease or power purchase agreement price.

A more complex version of the scenario described above involves locating the solar array far from the public facility that will receive financial benefit from the generation. These are sometimes referred to as “virtual net metering” models, though in Texas that moniker may not often strictly apply, since net metering is not required of most utilities by law. Still, municipal and cooperative utilities may be willing to support such a transaction, and within the competitive market customers are free to negotiate similar agreements with their retail electric providers.

Example

Other models are also possible. The municipal electric utility for San Antonio, CPS Energy, contracted to purchase solar energy generated from the Tessman Road Landfill. The landfill is owned by Republic Services, Inc., and instead of a traditional clay cap, the design places flexible solar panels on the surface of closed sections of the landfill. The flexible solar strips can be configured to maximize the hours of sunlight exposure throughout the year, depending upon a landfill's design and site contours.

The Tessman Road solar cover complements the landfill's existing biogas-to-energy system, which has operated since 2002, and electricity from both units may be used for onsite energy needs or sold to CPS Energy. The benefits of the solar project can be expanded by increasing the number of the solar strips as other sections of the landfill are closed.⁴⁰

⁴⁰ HDR, Inc., [Tessman Road Solar Landfill Cover](#).



Figure 12. Tessman Road Solar Landfill Cover, San Antonio, Texas.⁴¹

Inputs Used in Benefit-Cost Modeling

The table below presents key details of the hypothetical model system used for benefit-cost modeling. These inputs do not represent any specific, real-world example of an installed system, but are designed to illustrate a common application likely to be of interest to local governments, with technical specifications, costs and utility rates that approximate current pricing in Texas at the time of publication (summer 2016). The model is intended to serve as an illustration of current project economics, and forms the basis of a model template financial pro forma which can be customized by local government officials to meet the specific requirements of a locally-considered project.

In this case, the model is constructed to represent a large (multi-megawatt) solar energy system installed on public land adjacent to a public facility with high and consistent electric loads, such as a wastewater treatment plant. The solar energy system is assumed to be leased by the public entity from a third party owner who benefits from the federal investment tax credit and from a more modest (relative to the simple grid-tied solar assumption) utility incentive, and exercises an option to purchase the system after year 10. During the first 10 years, the major cost to the public entity is the lease payment; from year 11-30, the public entity takes responsibility for other operating expenses. The model assumes that 10 percent of the energy produced is exported to the grid, and that the public entity receives a lower value for these energy exports, reflective of a

⁴¹ Photo courtesy HDR, Inc.

utility's avoided cost rather than the full retail value. Finally, it assumes that the retail electric contract for the facility is on a flat, energy-only rate, and therefore that the installation does not benefit from reduction in demand charges. This configuration might be analogous to a public facility served by a rural electric cooperative that does not offer net metering to customers with distributed renewable generation.

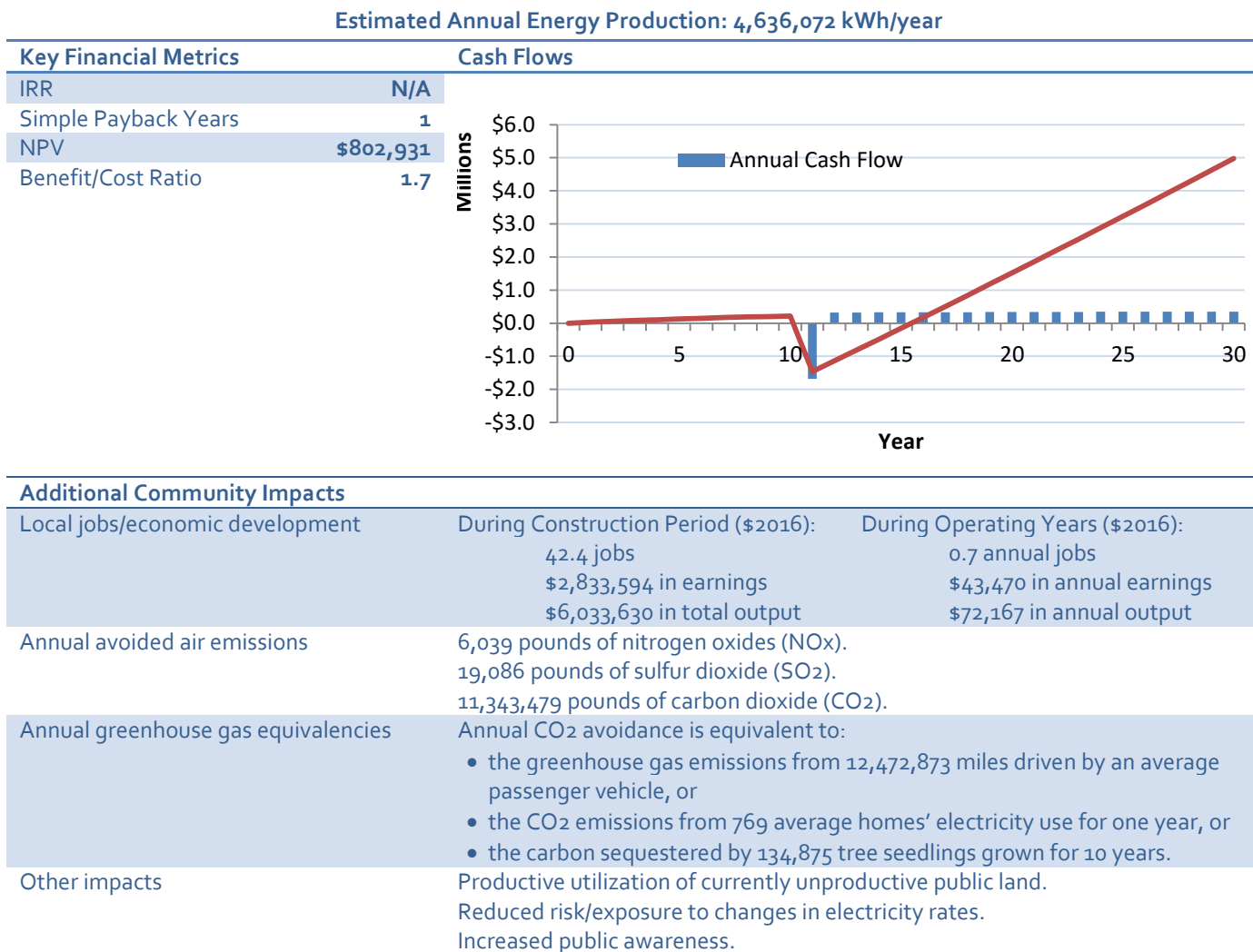
Table 3. Benefit-Cost Model Inputs – Model Application 2 – Solar on Landfills or other Underutilized Sites

Deal Structure:	Third party owned solar on public-owned land adjacent to a public facility with high and consistent energy consumption, such as a water treatment plant. Solar equipment is leased to the public buyer. System is located in Dallas.
PV System Specifications:	2.5 MW ground mounted single-axis tracking array oriented due south at 0 degree tilt. Estimated life 30 years.
Storage Specifications:	No storage
Lease Terms:	Starting monthly lease price: \$27,000/month. Annual escalator: 1.5%. Purchase option exercised at year 10: \$2.0 million.
Estimated Annual Operating Costs:	\$0 (covered by third party owner) during 10 year lease term. \$66,961 starting in year 11 (per NREL JEDI), escalated at 1.5% per year.
Site Loads and Excess Energy:	PV system sized to serve approximately 50% of facility baseload demand; 10% of PV energy is assumed to be exported to the grid.
Site Electric Bill Rates:	Charge for energy inflows: \$0.08 Credit for energy outflows: \$0.04 Demand charge: \$0/kW (energy-only rate)
Direct Financial Costs Modeled:	Lease payments, lease purchase option at year 11, operating and maintenance costs years 11-30.
Direct Financial Benefits Modeled:	Electric bill energy savings
Additional Community Impacts:	Local jobs and economic development. Avoided air emissions (CO ₂ , NO _x , SO ₂). Productive utilization of unproductive land. Reduced risk/exposure to changes in electricity rates. Increased public awareness.

Benefit Cost Model Results

Benefit cost model outputs, including direct financial benefit cost metrics and additional community impacts, are summarized in the table below.

Table 4. Benefit-Cost Model Outputs – Model Application 2 – Solar on Landfills or other Underutilized Sites



In this case, because the local government facility is on an energy-only rate, all of the financial benefit provided by the installation comes from reductions in energy purchased from the utility. Because the system is leased by the local government for the first 10 years, then purchased, the cumulative cash flow profile is relatively complex. During the first 10 years, calculation of the IRR and simple payback years is impossible because the up-front investment is zero. From the cash flow graph we can see that, once the purchase option is exercised at year 10, the purchase cost is balanced by energy savings in about 4 years.

Model Application 3. Solar on Shading Structures

General Description

Some solar installations are designed to offset purchased electricity and provide shade and shelter. These systems may be considered on public properties such as at parks, amphitheaters, parking lots or other outdoor facilities. The additional benefits of shade and shelter may be valued by comparing the alternative cost of providing shade and shelter in the absence of solar generation.

One challenge that often accompanies solar shading structure designs is finding a suitable electricity load to offset with the solar generation. Parking lots and public parks are not typically large consumers of electricity, or tend to consume most electricity at night for lighting. Either of these situations may result in a large fraction of the solar energy generated being exported to the grid, potentially unvalued in the economic analysis, or valued at significantly lower rates than retail electricity.

Example

An example of a solar shade structure is at the University of Texas Southwestern Medical Center in Dallas, which constructed a 300 kWdc solar array in its open parking lot in 2011. The system is estimated to save the facility over 415,000 kilowatt-hours each year – the equivalent of taking the carbon output of 56 passenger vehicles off the road – and covers 116 parking spaces, providing employees and guests with a cooler place to park.⁴²

The parking lot and shade structures are located across the street from the main medical center building, but are adjacent to a physical plant that provides a point of electrical interconnection to the entire medical center campus.

⁴² Solaire by SunPower, [University of Texas Southwestern Medical Center](#).



Figure 13. Parking Shade Structures at University of Texas Southwestern Medical Center⁴³

Inputs Used in Benefit-Cost Modeling

The table below presents key details of the hypothetical model system used for benefit-cost modeling. These inputs do not represent any specific, real-world example of an installed system, but are designed to illustrate a common application likely to be of interest to local governments, with technical specifications, costs and utility rates that approximate current pricing in Texas at the time of publication (summer 2016). The model is intended to serve as an illustration of current project economics, and forms the basis of a model template financial pro forma which can be customized by local government officials to meet the specific requirements of a locally-considered project.

In this case, the model is based on the simple grid-tied solar model but contains two distinctions. First, the assumed installed cost per watt is higher, due to the increased cost and complexity of installing shading structures relative to roof mounted solar. Second, the 77 covered parking spaces are assumed to be revenue-producing, and command an additional \$2 daily fee over uncovered parking, and the covered spaces are assumed to be utilized 50% of the time. All other assumptions are equivalent to the simple grid-tied solar model. This model is constructed to resemble solar-covered parking installed at an airport or other large facility where shaded parking spaces command a premium fee over non-shaded spaces.

⁴³ Photo courtesy of Solaire Generation.

Table 5. Benefit-Cost Model Inputs – Model Application 3 – Solar on Shading Structures

Deal Structure:	Local government owned, directly purchased without financing utilizing available utility incentive. System located in Fort Worth.
PV System Specifications:	200 kWdc ground mounted array oriented due south at 20 degree tilt. Estimated life 30 years.
Storage Specifications:	No storage
Installed Cost:	Total installed PV system cost \$550,000 (\$2.75/Wdc). Utility incentive of \$150,000 (\$0.75/Wdc). No federal tax credit or other grants. Net installed cost \$400,000.
Estimated Annual Operating Costs:	\$3,986 in year 1 (per NREL JEDI model)
Site Loads and Excess Energy:	PV system sized to serve approximately 50% of facility annual energy requirement; 10% of PV energy is assumed to be exported to the grid. 12% of kWdc PV system rating is assumed to contribute to demand reduction annually.
Site Electric Bill Rates:	Charge for energy inflows: \$0.08 Credit for energy outflows: \$0.08 Demand charge: \$5/kW Annual escalation rate: 1.5%
Direct Financial Costs Modeled:	Capital and operating costs.
Direct Financial Benefits Modeled:	Electric bill energy and demand savings. Increased parking fee revenue.
Additional Community Impacts Modeled:	Local jobs and economic development. Avoided air emissions (CO ₂ , NO _x , SO ₂). Reduced risk/exposure to changes in electricity rates. Increased public awareness.

Benefit Cost Model Results

Benefit cost model outputs, including direct financial benefit cost metrics and additional community impacts, are summarized in the table below.

Table 6. Benefit-Cost Model Outputs – Model Application 3 – Solar on Shading Structures

Estimated Annual Energy Production: 299,993 kWh/year		
Key Financial Metrics	Cash Flows	
IRR	11.2%	
Simple Payback Years	8	
NPV	\$307,385	
Benefit/Cost Ratio	2.2	

Additional Community Impacts	During Construction Period (\$2016):	During Operating Years (\$2016):
Local jobs/economic development	4.1 jobs \$275,431 in earnings \$584,165 in total output	0.1 annual jobs \$3,451 in annual earnings \$5,700 in annual output
Annual avoided air emissions	195 pounds of nitrogen oxides (NOx). 618 pounds of sulfur dioxide (SO ₂). 367,003 pounds of carbon dioxide (CO ₂).	
Annual greenhouse gas equivalencies	Annual CO ₂ avoidance is equivalent to: <ul style="list-style-type: none"> the greenhouse gas emissions from 398,971 miles driven by an average passenger vehicle, or the CO₂ emissions from 24.6 average homes' electricity use for one year, or the carbon sequestered by 4,314 tree seedlings grown for 10 years. 	
Other impacts	Reduced risk/exposure to changes in electricity rates. Increased public awareness.	

The financial pro forma template demonstrates best practice financial analysis and sheds light on the potential value of shading. In this case, although the installed cost of the system is higher than for a roof-mounted system, the additional revenue provided by the shaded parking spaces improves the key financial metrics significantly. Electric bill energy and demand savings are equivalent to the simple grid-tied solar model, but the value of shade now comprises over half of the total benefits provided by the system. While the assumptions made about the value of shaded parking spaces, and about the market potential for shaded covered parking opportunities applicable to local governments, should be treated with caution, the model demonstrates that additional revenue-producing attributes, apart from typical energy and demand savings values, can greatly improve the financial feasibility of such projects.

Model Application 4. Grid-Tied Solar with Energy Storage

General Description

Grid-tied solar combined with energy storage systems are designed to offset purchased electricity and to provide backup power to critical operations, such as emergency services, during outages or over extended periods of time. These systems also can store and shift energy consumption to minimize capacity charges in commercial uses, or to reduce usage during peak pricing periods where applicable.

Grid-tied solar with storage installations are, to date, rare. But with increasing interest in improving the resilience of the energy grid, especially during potentially long outages due to storms, such systems are gaining traction in the marketplace. Schools and other public facilities that may serve emergency services or shelter operations during prolonged outages seem to be the most likely candidates for solar combined with storage. Most current projects have been installed as part of research grants, but cost-effective opportunities are likely to be forthcoming as solar and storage costs decline, and as methods are developed for valuing and capturing the value provided by solar and storage systems.

Example

A 2015 solar and energy storage installation at the University of South Florida combines a 100 kilowatt solar array with 200 kilowatts of battery storage. The solar array provides shaded parking spaces on the roof of a parking structure, and the combined system also consists of two electric car chargers within the parking garage. Duke Energy Florida installed the system with support from a \$1 million federal grant.⁴⁴

⁴⁴ From [Duke Energy, University of South Florida St. Petersburg unveil solar battery project](#), Duke Energy, and [Duke Energy unveils solar power project at USF St. Pete](#), TBO (Tampa Bay Times online edition).



Figure 14. Solar and Energy Storage system at the University of South Florida⁴⁵

Benefit-Cost Modeling

The table below presents key details of the hypothetical model system used for benefit-cost modeling. These inputs do not represent any specific, real-world example of an installed system, but are designed to illustrate a common application likely to be of interest to local governments, with technical specifications, costs and utility rates that approximate current pricing in Texas at the time of publication (summer 2016). The model is intended to serve as an illustration of current project economics, and forms the basis of a model template financial pro forma which can be customized by local government officials to meet the specific requirements of a locally-considered project.

In this case, the model is based on the simple grid-tied solar model but also incorporates energy storage. The energy storage system modeled consists of four Tesla PowerWall systems, with energy, capacity and pricing as advertised. Additional benefits provided by storage include a time of use arbitrage value and resiliency value. Resiliency value was estimated with the US Department of Energy's ICE calculator using the most recent five year average Oncor-reported all-events (including storms) reliability metrics from 2009-2013. All other inputs were default values in the ICE calculator.⁴⁶

⁴⁵ Images courtesy of [Duke Energy Florida under Creative Commons License](#).

⁴⁶ 5 year average SAIDI was 237.8, and SAIFI was 1.3. Public Utility Commission of Texas, [Response of Oncor Electric Delivery Company LLC to PUC Staff's Second Request for Information, PUC Project No. 43512](#).

Table 7. Benefit-Cost Model Inputs – Model Application 4 – Grid-Tied Solar with Energy Storage

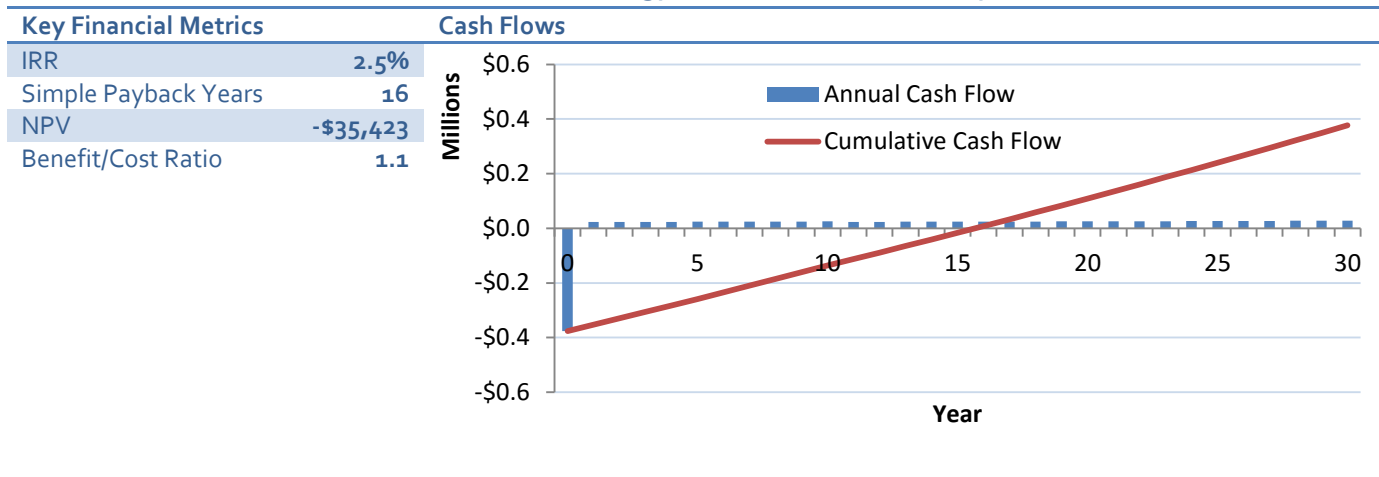
Deal Structure:	Local government owned, directly purchased without financing utilizing available utility incentive. System located in Fort Worth.
PV System Specifications:	200 kWdc rooftop array oriented due south at 20 degree tilt. Estimated life 30 years.
Storage Specifications:	26.4 kW, 25.6 kWh of energy storage
Installed Cost:	Total installed PV system cost \$500,000 (PV at \$2.50/Wdc). Total installed storage cost \$26,000. Utility incentive of \$150,000 (\$0.75/Wdc). No federal tax credit or other grants. Net installed cost \$376,000.
Estimated Annual Operating Costs:	\$3,986 in year 1 (per NREL JEDI model).
Site Loads and Excess Energy:	PV system sized to serve approximately 50% of facility annual energy requirement; 10% of PV energy is assumed to be exported to the grid; 12% of kWdc PV system rating is assumed to contribute to demand reduction annually.
Site Electric Bill Rates:	Time of use arbitrage value: \$0.02 Charge for energy inflows: \$0.08 Credit for energy outflows: \$0.08 Demand charge: \$5/kW Annual escalation rate: 1.5%
Direct Financial Costs Modeled:	Capital and operating costs.
Direct Financial Benefits Modeled:	Electric bill energy and demand savings. Time of use arbitrage (for storage).
Additional Community Impacts:	Local jobs and economic development. Avoided air emissions (CO ₂ , NO _x , SO ₂). Resiliency value (for storage). Reduced risk/exposure to changes in electricity rates. Increased public awareness.

Benefit Cost Model Results

Benefit cost model outputs, including direct financial benefit cost metrics and additional community impacts, are summarized in the table below.

Table 8. Benefit-Cost Model Outputs – Model Application 4 – Grid-Tied Solar with Energy Storage

Estimated Annual Energy Production: 299,993 kWh/year



Additional Community Impacts		
Local jobs/economic development	During Construction Period (\$2016): 3.9 jobs \$263,412 in earnings \$558,674 in total output	During Operating Years (\$2016): 0.1 annual jobs \$3,451 in annual earnings \$5,700 in annual output
Annual avoided air emissions	195 pounds of nitrogen oxides (NOx). 616 pounds of sulfur dioxide (SO ₂). 365,873 pounds of carbon dioxide (CO ₂).	
Annual greenhouse gas equivalencies	Annual CO ₂ avoidance is equivalent to: <ul style="list-style-type: none"> the greenhouse gas emissions from 397,742 miles driven by an average passenger vehicle, or the CO₂ emissions from 24.5 average homes' electricity use for one year, or the carbon sequestered by 4,301 tree seedlings grown for 10 years. 	
Other impacts	Resiliency valued at \$1,804.50 annually to electric utility. Reduced risk/exposure to changes in electricity rates. Increased public awareness.	

The financial pro forma indicates a slight penalty to project economics resulting from the addition of energy storage relative to the simple grid-tied storage model. While total installed costs increased, the additional value provided by the time of use arbitrage opportunity was not high enough to overcome the increased cost.

The value of resiliency generated from the DOE ICE model was significant at \$1,804.50 per year. If that value were considered a direct financial benefit to the local government making the investment in the system, the project economics overall would be slightly improved relative to the simple grid-tied storage model. However, at this time the resiliency value is most properly considered as accruing to the electric utility rather than directly to the customer. As mechanisms emerge in Texas enabling storage to participate in the market in new ways, it is

possible that all or a portion of this value could accrue to the customer. It is also possible that utility incentives could be provided to compensate the investor/customer for value that accrues to the utility.

Avoided emissions and their equivalencies are slightly less than in the simple grid-tied solar model in order to account for inefficiencies in storing and discharging energy in the battery storage system under a daily cycling regime.

Model Application 5. Mobile Solar with Energy Storage

General Description

Mobile power supplies may combine solar (and possibly other generator types) with battery storage, and are mounted on wheeled trailers or skids. With solar onboard, these versatile power supplies stay charged up and may be transported to areas of need. They are typically used to supply power for short (a few hours or days) or medium (a few days or weeks) durations to relatively low power consuming loads, such as emergency lights and signs, laptops or other electronics, small refrigerators, or tools. They operate silently and produce no air emissions, or reduce air emissions that would otherwise have been produced by portable gasoline or diesel generators. As such, they are a versatile power solution for a variety of needs, and can be deployed to power loads where grid electricity is unavailable (such as at parks or other open spaces) or during power outages.

Local governments may have a wide variety of applications that could be served with mobile solar with storage solutions, ranging from practical to whimsical, and may value the application of solar in such instances in ways that direct financial analysis cannot adequately express.

- Libraries may offer bookmobiles or mobile learning centers that, in addition to carrying physical books may provide users with access to the internet via laptops powered by the sun.
- Economic development agencies may offer mobile workforce centers that provide job seekers with search and application tools.
- Emergency response teams may value mobile work centers that enable continuous service provision in the event of widespread outages.
- Transportation agencies may need moveable power sources to temporarily provide power to traffic control systems at busy intersections after an interruption.
- Cultural arts programs may benefit from portable power systems that power sound stages or enable credit card transactions at entry gates of outdoor events.
- Environmental centers may utilize mobile power systems to demonstrate the viability of sustainable energy in local homes and businesses.

In each of these cases, modeling the direct financial benefits and costs of a proposed investment may not adequately capture the value of additional community benefits such as increased public awareness, flexibility, or silent operation that mobile solar plus energy storage provides.

Examples

[Event Solar Power's Solar Shuttle™](#) is available for rental in the Dallas/Fort Worth metroplex and beyond. The trailer consists of a 2,150 WDC solar array that can be tilted and positioned as desired and 32 kWh of battery

storage. It is capable of powering sound stage amplifiers and related equipment for up to 5,000 or more attendees. It can also power welders, lights, audio and video equipment, power tools, and many other types of loads that plug into a standard 120 volt home or office electrical outlet. Event Solar Power also makes available two smaller solar plus storage systems that can power audio amplifier systems, portable video systems, laptops, temporary lighting fixtures, and other applications.⁴⁷

The owner of the Solar Shuttle™ provided the following estimate of the costs to put together a power system for a similar trailer. This estimate does not include the cost of the trailer or vehicle, and does not have redundant systems that can run independently.

- Solar panels: \$2,500 (~2,400 watts)
- Custom racking \$4,000
- Charge controller: \$1,000
- Batteries: \$2,500
- Inverter: \$5,000 (5 > kW, stand-alone)
- Miscellaneous items and hardware: \$2,500
- Total: \$17,500



Figure 15. Solar Shuttle™ Mobile Power Trailer by Event Solar Power

[SolarCraft](#) is a Texas-based designer and manufacturer of stand-alone integrated power and control systems primarily used in the industrial, oil field, and transportation sectors. It designs and builds hybrid solar power

⁴⁷ Specifications from [Event Solar Power's web site](#).

systems to power scientific equipment and other remote applications. For example, some remote sites are well suited for solar power during summer months, but receive extremely limited solar insolation in the winter. In some cases, a "smart" generator is best suited for an application, and will automatically start up to maintain battery charge levels. When considering an ideal power source for a specific application, SolarCraft evaluates the potential of various power sources, including solar, wind, propane or natural gas fueled generators, alone and in combination, and considers battery requirements, power cycling, solar resources, maintenance, and site access. The goal is to design and recommend highly reliable systems that optimize costs with power output to effectively power the load year round.⁴⁸



Figure 16. Mobile Hybrid Power Sources by SolarCraft and Black Sage Technologies⁴⁹

[Black Sage Technologies](#) offers small power systems mounted on a trailer frame with up to three independent power sources to provide reliable, self-sustained power for diverse applications and environments. The power systems require no refueling, no filter changes, and offer silent operation for deploying sensors, camera and antennas in security, remote power, disaster relief, emergency preparedness, and lighting applications. The trailer shown at the right includes one 315-watt solar panel, a 250-watt small wind turbine with a telescoping mast, a 320 Amp-hour battery bank, and a 1500 watt inverter and is priced at \$12,000-15,000.⁵⁰

Smaller versions of these solar plus storage applications are also available. A common public application involves traffic advisory signs and message boards. In these applications, construction crews can program and place a message at needed locations without the hassle of refueling generators. Solar arrays and battery banks are typically sized to enable the signs to operate for several days even in poor weather conditions.

⁴⁸ See SolarCraft's information about [hybrid mobile power systems](#).

⁴⁹ Photos courtesy of SolarCraft and Black Sage Technologies.

⁵⁰ Pricing data from Overstock.com [here](#) and [here](#).



Figure 17. Solar Powered Mobile Message Boards by US Barricades⁵¹

Evaluating Benefits and Costs

Mobile solar combined with storage systems currently tend to be cost-effective only in applications with relatively small loads and consistent use, and where hooking up to a grid connection is costly or impractical, such as powering emergency road signs.

A common application of mobile solar and storage is with road construction warning signs and message boards. These systems are able to harvest and store the energy needed for up to several days of operation in a single day on a small footprint, perhaps with just one or two solar panels, may be easily moved to new locations, operate silently and require little maintenance.

Larger applications of mobile solar and storage intended to serve as backup power for larger loads tend to be impractical and not cost-effective relative to other options for several reasons:

- The area of solar panel coverage required to harvest necessary energy may be too large to fit on a mobile trailer or skid mount.
- Limited run times and utilization rates reduce the financial benefits obtained from these systems.
- Off-grid systems tend not to be eligible for utility-sponsored incentives.

Further, the costs of solar plus storage systems must be weighed against other options for supplying backup power, including portable gas or diesel fueled generators, which are typically less expensive.

In addition, many public emergency services functions that place a high value on their ability to consistently provide service, such as 9-1-1 call centers, may achieve flexibility and resiliency in the event of outages through alternative means. These may include installing fixed infrastructure such as diesel backup generators or battery-only systems on the buildings in which these centers are located, or placing critical service infrastructure in the

⁵¹ See [US Barricades](#).

cloud, enabling the service provider to coordinate service provision with other nearby jurisdictions, quickly rerouting calls and functions to uncompromised locations.

Benefit-cost analysis of mobile solar plus storage systems requires answering the following questions:

- What are the power requirements the mobile unit must be able to serve?
 - How much instantaneous power draw must the unit be able to handle?
 - How much total energy per hour? Per day?
 - Over what duration must the system be designed to provide backup power?
- How much space do I have for solar panels on a trailer or skid mount? Will it be sufficient to produce the energy needed over the required duration of service?
- What is the anticipated utilization rate of the mobile solar plus storage solution under consideration?
- What other means of providing backup power or service functionality exist? What are the capital and operating costs of these alternatives, and how do they compare to mobile solar plus storage?

Because mobile solar and energy storage systems are highly varied and typically customized to individual uses, Frontier did not create a model pro forma template for evaluating cost-effectiveness. Instead, indicative pricing for some types of mobile solar and energy storage systems is provided in the narrative above. The value to a local government of investing in these systems may not be entirely embodied in the financial analysis, which would include decreased maintenance costs relative to conventional generators. Other features of such systems, such as portability, versatility, silent operation, extended use during outages, and visibility to the public may provide additional community benefits.

4. Key Findings

Frontier analyzed the benefits and costs of selected solar and energy storage applications and produced financial pro forma tools to assist local governments in evaluating these technologies. Key findings are presented below.

- | | |
|--|---|
| General Findings | <ul style="list-style-type: none">• Solar and energy storage technologies are rapidly decreasing in cost due to technological and efficiency improvements and manufacturing scale, and are becoming increasingly cost-effective in local government applications in Texas.• Solar and energy storage technologies may be deployed in a wide variety of scales, applications, and contract structures that may be of interest to local governments.• Local government officials in Texas are increasingly coming into contact with solar and energy storage technologies, and could benefit from uniform, best-practice approaches to evaluating their benefits and costs. |
| Solar and Energy Storage in the Context of Energy Efficiency | <ul style="list-style-type: none">• Many conventional energy efficiency measures may be more cost-effective than investments in solar and energy storage, and should be investigated and prioritized by local governments looking to reduce energy costs. Reducing a facility's annual energy needs first has a subsequent benefit of reducing the size and cost of solar and energy storage systems needed to serve those needs.⁵² |
| Cost-Effectiveness of Solar | <ul style="list-style-type: none">• Many simple grid-tied solar energy systems are currently cost-effective for local governments in Texas, particularly when direct costs are reduced with grants or utility incentives, or when equipment is leased or energy is purchased from a third party owner.• Additional direct value streams, such as those deriving from premiums on fee-based covered parking spaces, can improve the cost-effectiveness of potential solar investments. |
| Cost-Effectiveness of Energy Storage | <ul style="list-style-type: none">• Energy storage technologies, when paired with solar generation, are not likely to be cost-effective in Texas currently as a strategy for managing demand or shifting energy consumption to less-expensive hours, but may become so within the next few years as costs decline and as market structures emerge to monetize storage-enabled services. |
| Cost-Effectiveness of Mobile Solar plus Energy Storage | <ul style="list-style-type: none">• Mobile solar plus energy storage backup power units are unlikely to be cost-effective in Texas currently except in applications where anticipated loads are small, predictable, and often-utilized, such as for powering emergency signals and messaging signs. |
| Best Practice Model Templates | <ul style="list-style-type: none">• Model applications and accompanying financial pro forma templates provided with this report may be adapted for use by local officials evaluating potential investments in solar and storage. |

⁵² The State Energy Conservation Office (SECO) provides free energy audits as a resource for local governments through its [Preliminary Energy Assessment \(PEA\)](#) program.

Appendix A

Complete list of local government solar initiatives, from Solar Powering Your Community: A Guide for Local Governments, Second Edition, January 2011. <http://www.nrel.gov/docs/fy11osti/47692.pdf>.

- Organizing and Strategizing a Local Solar Effort
 - Create a Solar Advisory Committee or Task Force
 - Hire or Designate a Local Solar Coordinator
 - Survey Residents and Businesses to Identify Barriers
 - Conduct an Installation Baseline Survey
 - Establish Solar Installation Targets
 - Include Solar in Broader City, County, or Regional Planning Efforts
- Making Solar Affordable for Residents and Businesses
 - Renewable Portfolio Standards
 - Cash Incentives
 - Feed-In Tariffs
 - Third party Residential Financing Models
 - Property Assessed Clean Energy Financing
 - Low-Interest Loans
 - Group Purchasing
 - Community Solar
 - Property and Sales Tax Incentives
- Updating and Enforcing Local Rules and Regulations
 - Solar Access and Solar Rights Laws
 - Solar-Ready Building Guidelines
 - Streamlined Solar Permitting and Inspection Processes
 - Code Official Training
 - Installer Licensing and Certification
- Improving Utility Policies and Processes
 - Interconnection Standards
 - Net-Metering Rules
 - Rate Structures that Appropriately Value Solar

- Creating Jobs and Supporting Economic Development
 - Recruit the Solar Industry
 - Develop Local Workforce Training and Education Programs
- Educating and Empowering Potential Customers
 - Consumer Outreach and Education Programs
 - Demonstration Projects with an Educational Component
 - Customer Assistance Programs
 - Solar Mapping as an Outreach Tool
 - Solar in K-12 Curriculum
- Leading By Example with Installations on Government Properties
 - Identify Optimal Installation Locations
 - Standardize Solicitations for Solar Installations
 - Select the Appropriate Financing Mechanism
 - Tax-Exempt Financing
 - Tax Credit Bond Financing
 - Third party Finance Models
 - Using Local Funds in Combination with Third party Finance Models
 - Performance Contracting
 - Commission the Solar Energy System and Ensure Quality Operations
 - Host Wholesale Power Generators on Local Government Land or Facilities

Appendix B

The City of Plano has undertaken a number of initiatives to encourage solar adoption community-wide. These initiatives include:

- \$MART Energy Loans for residential energy improvements
- The Great Update Rebate home improvement program
- Green Business Certification program
- Close relationship with Plano Solar Advocates, a grass-roots volunteer group, which:
 - Sponsors outreach events such as the Learn2LiveGreen Expo, Earth Day Texas, Collin County Farmers Market, local Eco Fairs
 - Participates in Plano's Comprehensive Plan updates and Buildings and Fire Codes, Net Metering, and Real Estate Valuation working groups
 - Coordinates solar activities at local schools
 - Organizes Solarize Plano projects resulting in discounted group purchasing of solar for homeowners

Appendix C

North Central Texas Council of Governments Solar Energy Potential on Contaminated Lands (next page)

North Central Texas Council of Governments Solar Energy Potential on Contaminated Lands

