Value of Residential Solar in Texas

Prepared for:

TEXAS SOLAR ENERGY SOCIETY

dunsky Energy + Climate

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Submitted to:

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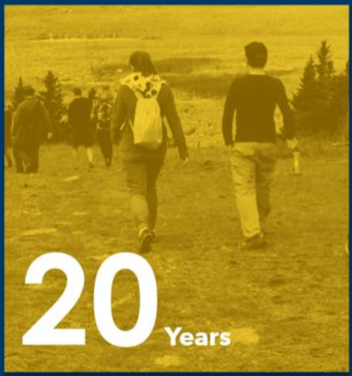
About Dunsky



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Executive Summary

Since 2021, Texas has witnessed significant economic and population growth, leading to increased electric demand. The system operator, the Electric Reliability Council of Texas (ERCOT), expects the summer net peak demand to grow from 82 GW today to about 90 GW by 2030. Furthermore, the anticipated influx of large power consumers such as data centers, crypto mining, hydrogen production, as well as the electrification of buildings, transportation and industry, could drive the system's peak demand to 163 GW by the end of this decade. If the generation and transmission buildout does not keep up with the anticipated increase in the pace and magnitude of electric demand, ERCOT could face a significant capacity shortfall and a threat to its system reliability.

Distributed Energy Resources (DERs), such as rooftop solar, will play a crucial role in helping to meet these emerging system needs and can alleviate constraints on the generation and transmission system. However, the total installed rooftop solar capacity in ERCOT is currently less than 3% of its technical potential. Inconsistent compensation policies among non-competitive utilities are seen as a barrier to rooftop solar reaching its full potential. There is an opportunity for utilities to revise and align compensation mechanisms that consider the full benefit that solar PV can contribute to the grid and system reliability. The Texas Solar Energy Society (TXSES) commissioned the "Value of Solar: Texas" to provide an in-depth analysis of the grid and public health benefits of Residential Solar PV within ERCOT over 25 years (2025 to 2050).

Starting from the National Standard Practice Manual (NSPM), the study shortlisted nine avoided-cost components based on their significance, monetizability, and relevance to Texas. The components were categorized as follows:

- **Generation:** This category captures the value of solar to the ERCOT wholesale market. It comprises avoided energy, avoided ancillary costs, wholesale price suppression benefits, avoided risk "premiums" and avoided transmission and distribution (T&D) line losses.
- **Delivery (T&D):** This category captures the value of solar to the transmission and distribution system and includes the avoided transmission and distribution capacity costs.
- **Public:** This category captures solar's public health benefits, including reducing air pollutants and GHG pollution.

Key Findings:

1. **Solar offers substantial benefits to Texas's grid:** With the anticipated increase in electric demand, Texas requires all the generation capacity it can obtain. Even with the rise of rooftop solar, a significant amount of energy still needs to be generated. However, it alleviates some of the burden on the utilities and the state by reducing the need for additional infrastructure. The analysis found that in 2025, the overall value of solar in ERCOT will be about 27¢/kWh. About 55% of the total value (15¢/kWh) is realized in the generation, transmission, and distribution system, while the remaining 45% (12¢/kWh) is realized through air pollutant and emission reduction benefits.
    - Among the grid benefits, the largest component is **avoided energy costs** (9¢/kWh), followed by (ii) wholesale price suppression benefits (1¢/kWh). The

benefits of avoided energy costs and wholesale price suppression are driven by the stronger coincidence of solar generation and the hourly wholesale energy price in ERCOT.

- In 2025, the benefits from reducing greenhouse gas pollution (10¢/kWh) make up 90% of the overall public benefits, followed by benefits from reducing air pollutants (2¢/kWh). However, this value is expected to decrease significantly over time due to the anticipated drop in marginal emission intensity in ERCOT.

2. **The current export credits may not accurately reflect the value of solar:** In their Solar Buyback Plans, non-competitive utilities in Texas offer a wide range of export credits (from 3 ¢/kWh up to 19 ¢/kWh). This disparity in solar compensation exists because utilities have different ways of evaluating the grid benefits from solar. Typically, utilities do not consider solar's additional benefits to the wholesale market, such as avoided risk premium costs, ancillary costs, and price suppression benefits, as well as its benefits to the T&D system in the form of avoided transmission and distribution capacity costs. As a result, these export credits may not accurately reflect the value solar provides to the system.
3. **Solar PV provides several intangible benefits:** In addition to the value quantified above, distributed solar provides significant tangible and intangible benefits to the Lone Star State.
   - Job and Local Economic Impacts: Distributed solar can stimulate local economies by providing employment opportunities. According to the NREL, constructing one MW of residential solar could result in twelve to twenty full-time equivalent direct jobs that year. In addition, solar can bring stable and predictable revenue streams to communities through employee wages and the local supply chain involved in installing and maintaining solar PV systems.
   - Poverty Alleviation and Energy Equity: Solar energy addresses environmental justice concerns and can promote poverty alleviation and energy equity through electricity bill savings and buffer against price volatility.

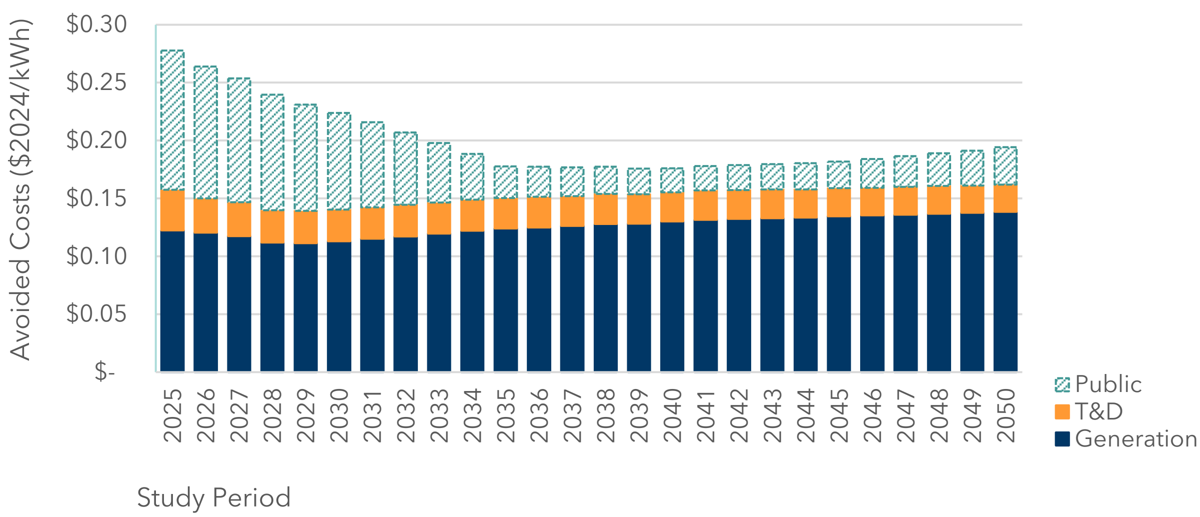

Figure 0-1: Value of Solar in Texas 2025-50

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1. Introduction

Texas has experienced significant economic and population growth, leading to a 15 GW increase in electric demand over the last three years.[1,2] Its system operator, the Electric Reliability Council of Texas (ERCOT), anticipates peak demand reaching 90 GW by the decade's end. However, early indications already suggest that this estimate might be conservative. Transmission Service Providers (TSPs) in the state foresee a substantial surge in demand from major power consumers such as crypto mining, hydrogen-related manufacturing, transportation electrification and data centers. Moreover, House Bill (HB) 5066 mandates that ERCOT incorporate these potential loads into its load planning assessment. Consequently, ERCOT has revised its load forecasts, projecting that the system load could surge from 82 GW in 2024 to 164 GW by 2030. [3,4,5] As seen in Figure 1-1, by 2030, the range in forecasts represents a 74 GW uncertainty in peak demand.

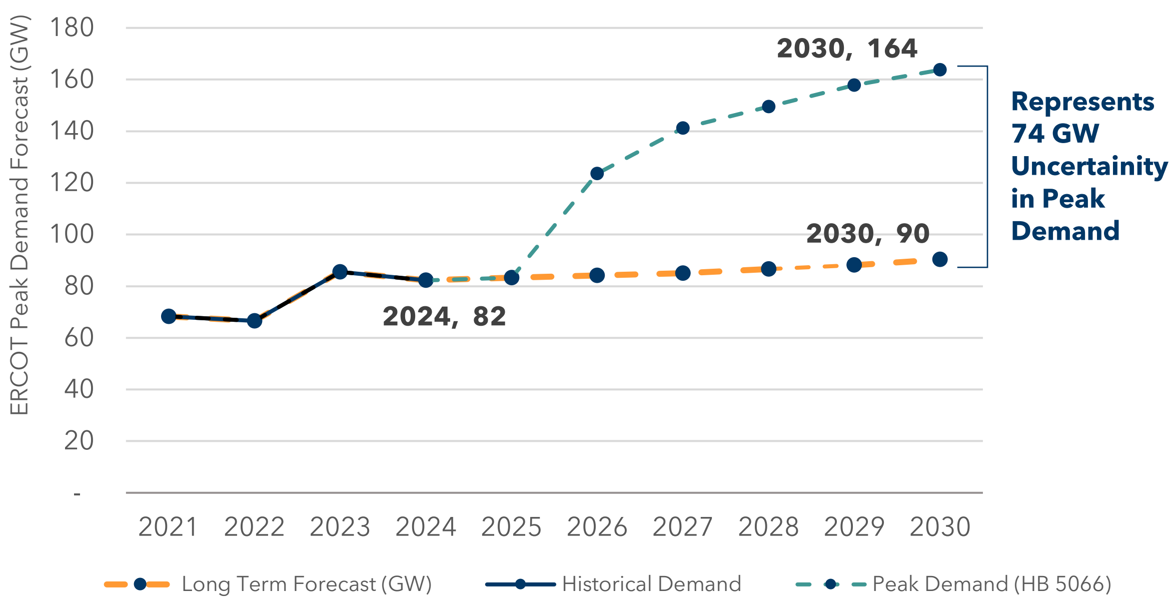

Figure 1-1: Electric Demand Forecast in ERCOT[6]

[1] In the fourth quarter of 2023, real gross domestic product (GDP) for Texas grew at an annual rate of 5.0%, well ahead of the U.S. for the sixth quarter in a row. Office of the Texas Governor. "Texas Economy Again Expands Faster Than Nation." Texas Governor's Office, April 2, 2024. Office of the Texas Governor | Greg Abbott

[2] Texas' population increased by 470,708 people since July 2021, the largest gain in the nation. Wilder, Kristie. "Texas Population Passes the 30-Million Mark in 2022." U.S. Census Bureau, March 30, 2023. Census

[3] Texas Legislature. "Bill Text: TX HB5066 | 2023-2024 | 88th Legislature | Enrolled." LegiScan, June 13, 2023. Bill Text: TX HB5066 | 2023-2024 | 88th Legislature

[4] ERCOT. "2024 Regional Transmission Planning (RTP) Load Review Update: April 2024." April 8, 2024. https://www.ercot.com/files/docs/2024/04/08/2024_RTP_Load_Review_Update_April_2024_RPG.pdf.

[5] ERCOT's Long-Term Forecast provides an hourly forecast for the next ten years based on projected economic data and historical weather from 2006 to 2020. ERCOT. "Load Forecast." Electric Reliability Council of Texas. Accessed June 30, 2024. https://www.ercot.com/gridinfo/load/forecast.

[6] Regional Transmission Planning (RTP) is an annual system-wide analysis that addresses region-wide reliability and economic transmission needs and recommends specific planned improvements to meet those needs for the upcoming six years.

This upward revision in load forecast poses a dual challenge. Over the next five years, ERCOT needs to expand both its generation capacity to meet the anticipated demand increase and its transmission capacity to deliver this generation to load centers.

As of April 2024, ERCOT had 1,775 active generation interconnection requests totaling 346 GW.[7] As seen in Figure 1-2, this includes 155 GW of solar, 141 GW of battery storage, 35 GW of wind, and 15 GW of gas that is expected to be deployed over the next five years. This generation mix is more diverse than previous portfolios, is being built faster, and is more geographically dispersed from load centers. Matching these diverse generation and load profiles requires greater balancing resources and a significant expansion of transmission systems.

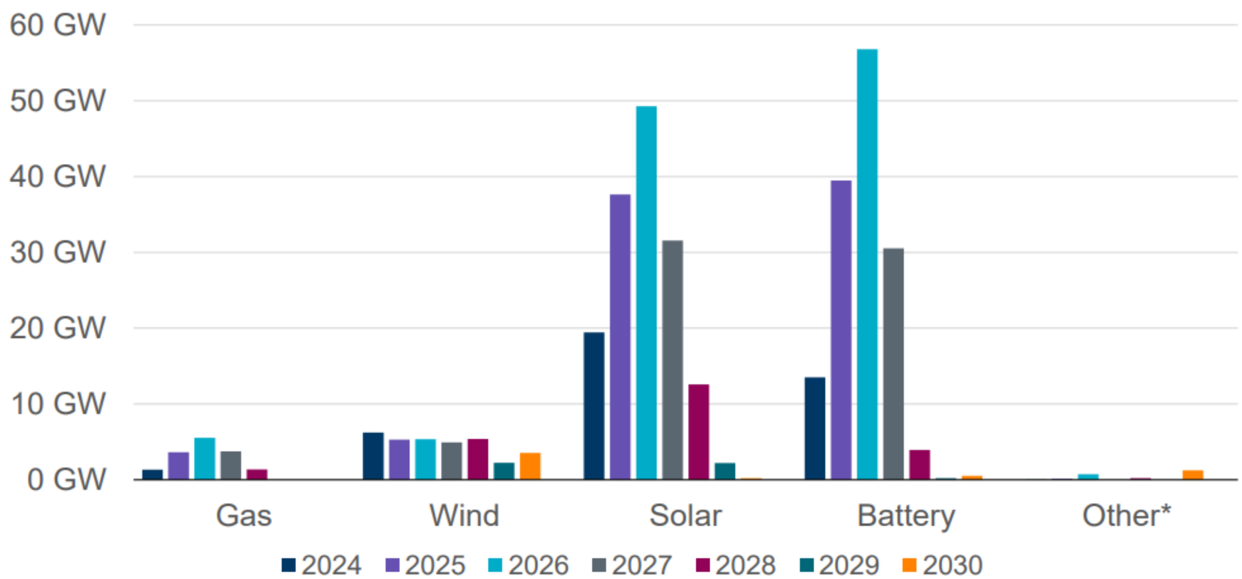

Figure 1-2: Interconnection Queue Capacity by Fuel Type in ERCOT[8]

As seen in Figure 1-3, ERCOT typically has a faster transmission buildout process (4 -6 years) than FERC (8-13 years). Despite this, ERCOT has raised concerns that the forecasted pace of load growth could exceed the pace at which transmission capacity can be built to support it.[9]

If the transmission buildout does not keep up with the pace and magnitude needed to support the anticipated increase in electric demand, ERCOT could face a significant capacity shortfall and a threat to its system reliability.

[7] ERCOT. "ERCOT Monthly Operational Overview: April 2024." May 16, 2024. https://www.ercot.com/files/docs/2024/05/16/ERCOT-Monthly-Operational-Overview-April-2024.pdf.
[8] ERCOT. "ERCOT Monthly Operational Overview: April 2024." May 16, 2024. https://www.ercot.com/files/docs/2024/05/16/ERCOT-Monthly-Operational-Overview-April-2024.pdf.
[9] ERCOT. "CEO Update: April 2024." April 22, 2024. https://www.ercot.com/files/docs/2024/04/22/5%20CEO%20Update.pdf.

Customer-sited solar PV is a valuable resource for meeting emerging electricity system needs. By providing localized generation, these resources can greatly enhance the grid's resilience and reliability and, when paired with energy storage, alleviate the strain on the generation and transmission systems, particularly during extreme weather events. Furthermore, solar PV can reduce consumer energy costs and minimize the necessity for costly infrastructure investments and upgrades.

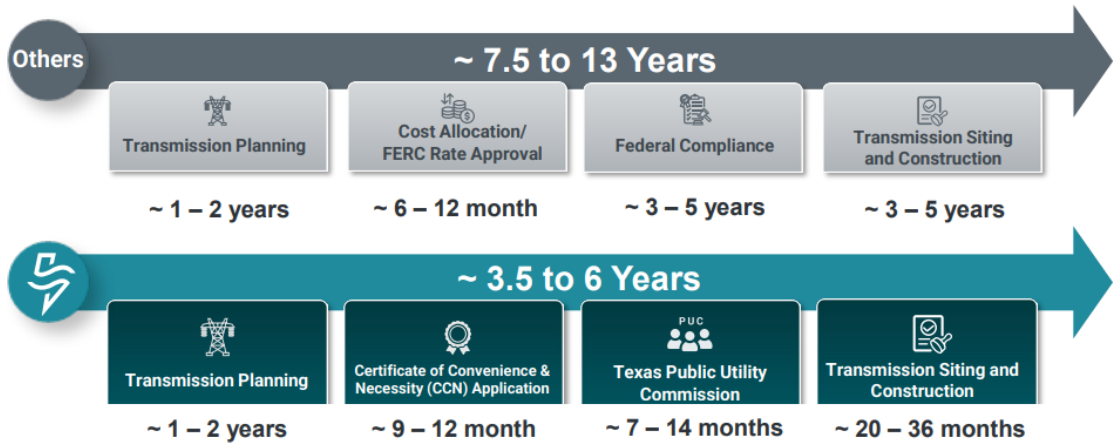

Figure 1-3: Typical Timelines for ERCOT and FERC Transmission Planning[10]

Texas has among the best solar resources in the United States. The state's diverse geographic conditions, including vast open spaces and a high number of sunny days, are ideal for solar. Further, areas without significant tree canopy coverage tend to have more small buildings suitable for solar PV. As a result, within the US, the percentage of small buildings ideal for solar PV is highest in Texas, southern California, Florida, and Louisiana. As seen in Figure 1-4, more than 90% of the small buildings in Texas are suitable for rooftop solar PV. As such, the National Renewable Energy Laboratory (NREL) reports that the total technical potential for rooftop solar power in Texas is nearly 100 GW, with about 60% of this potential existing within the small building sector.[11,12]

Despite such a high solar potential, Texas has tapped less than 3% of its technical capacity. In contrast, California, the nation’s leader in rooftop solar, has tapped just more than 10% of its potential. This essentially boils down to the economics of rooftop solar for customers. Only a few municipalities (Austin, San Antonio, and the City of Brenham) and about a dozen retail providers offer any bill credit for energy exports to the grid from distributed solar. As the growth of customer-sited solar PV in Texas is expected to involve many small, unregistered customer-owned solar photovoltaic (PV) installations, it's important to provide fair and economically efficient bill credits based on a comprehensive assessment of the electric system benefits these systems offer to the grid. This will encourage and support the sustainable growth of distributed solar PV in Texas.

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[10] ERCOT. "CEO Update: April 2024." April 22, 2024. https://www.ercot.com/files/docs/2024/04/22/5%20CEO%20Update.pdf.
[11] Gagnon, Pieter, Robert Margolis, Jennifer Melius, Caleb Phillips, and Ryan Elmore. "Rooftop Solar Photovoltaic Technical Potential in the United States: A Detailed Assessment." National Renewable Energy Laboratory, January 2016. https://www.nrel.gov/docs/fy16osti/65298.pdf.
[12] Assumes buildings with less than 5000 sqft.

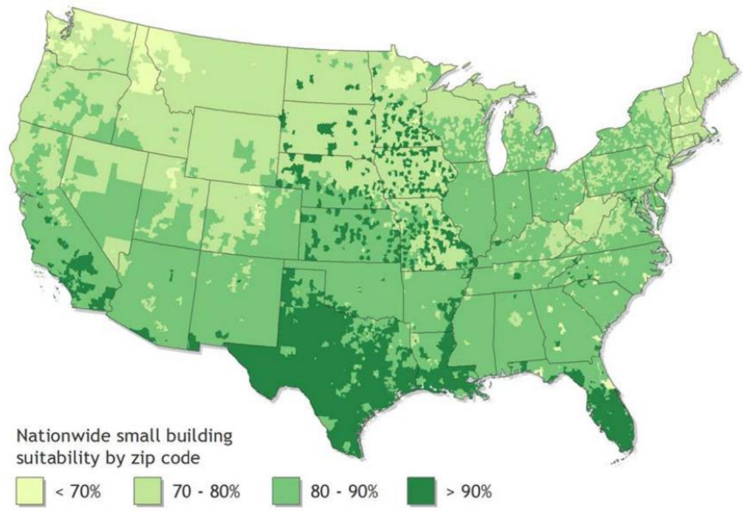

Figure 1-4: Percentage of small buildings suitable for PV in each ZIP code in the continental U.S[13]

ERCOT's total installed rooftop solar capacity was less than 3% of its technical potential.[14,15,16]

Several jurisdictions throughout North America have conducted value of solar (VOS) studies to comprehensively identify and determine the tangible benefits of solar PV to the electric grid. These studies have been crucial in evaluating existing net-metering regimes and developing fair and transparent compensation frameworks for distributed generation. The **Texas Solar Energy Society (TXSES) commissioned this study to quantify Distributed Solar PV's generation, delivery, and public value within ERCOT territory.[17]** The study aims to produce a robust, defensible analysis of Distributed Solar PV's value within Texas, underscore distributed solar generation's economic, public health, and grid-related benefits, and facilitate informed policymaking and regulatory decisions, thereby supporting grid reliability and Texas's clean energy growth in a fair and balanced manner.

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[13] NREL. "Rooftop Solar Photovoltaic Technical Potential in the United States: A Detailed Assessment." National Renewable Energy Laboratory, January 2016. https://www.nrel.gov/docs/fy16osti/65298.pdf.
[14] ERCOT. "Unregistered DG Installed Capacity Quarterly Report." Last updated November 27, 2023. Accessed June 30, 2024. https://www.ercot.com/mp/data-products/data-product-details?id=NP16-533-M.
[15] Total unregistered solar PV in ERCOT is expected to be 2.5GW. ERCOT. "Report on Existing and Potential Electric System Constraints and Needs." December 2023. https://www.ercot.com/files/docs/2023/12/22/2023-Report-on-Existing-and-Potential-Electric-System-Constraints-and-Needs.pdf.
[16] Dutzik, Tony, Abigail Ham, and Johanna Neumann. "Rooftop Solar on the Rise: 2024." Frontier Group and Environment America Research & Policy Center, February 2024. https://cdn.houstonpublicmedia.org/wp-content/uploads/2024/02/13111326/Rooftop-Solar-on-the-Rise-2024.pdf.
[17] Although the analysis was undertaken for the deregulated market in ERCOT, the values established in this study apply to the entire grid and could apply to municipal utilities and electric cooperatives within ERCOT.

2. Study Approach

A **Value of solar** (VOS) study is a detailed analysis of the economic and public benefits of grid-connected solar photovoltaic (PV) systems. It aims to quantify the economic value of solar energy to the grid and the public, helping policymakers, utilities, and regulators make well-informed decisions regarding energy policies, regulations, and incentives for solar.

The VOS study framework can be broken down into three high-level steps as outlined below in Figure 2-1:

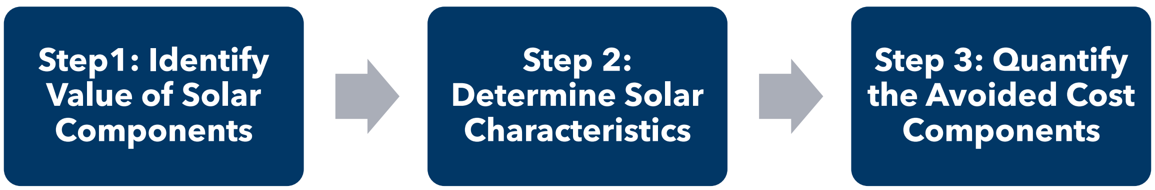

Figure 2-1: Study Approach for Value of Solar Assessment

- For **Step 1**, the National Standard Practice Manual (NSPM) and other relevant VOS studies were used to identify the generation, delivery, and public components typically considered for VOS studies.[18] The suitability of those components was then evaluated and shortlisted based on their **significance, monetizability, and relevance** to the Texas grid. The VOS components that could not be quantified were qualitatively described within the study. Generation and Delivery benefits reduce overall system costs and are therefore monetizable to customers, but the public benefits represent externality benefits that can be used to justify solar-supportive policies and public investments.
- Next, in **Step 2**, the solar characteristics of typical BTM solar installations in Texas were evaluated, such as annual production, solar production profile, the proportion of self-consumption & exports, and the effective load-carrying capability (ELCC).
- Finally, in **Step 3**, the solar characteristics were leveraged to quantify the avoided cost components and arrive at a comprehensive picture of the value BTM solar PV installations offer to Texas' electricity system, quantifying the monetizable benefits, and qualitatively identifying additional benefits.

The following sections provide more details about how these steps were applied to identify and develop the generation, delivery, and public value for solar.

[18] National Energy Screening Project. National Standard Practice Manual for Benefit-Cost Analysis of Distributed Energy Resources. August 24, 2020. https://www.nationalenergyscreeningproject.org/wp-content/uploads/2020/08/NSPM-DERs_08-24-2020.pdf.

Generation Value Components

Based on the NSPM and other VOS studies, Dunsky first enlisted all the components attributed to the wholesale market or generation system. Then, each component was assessed for its significance, monetizability, relevance to the ERCOT system, and whether it could be quantified in this study.

Table 1: Generation Value Components and their Consideration for Texas' VOS Assessment (NSPM).

Utility System Impact	Significant	Monetizable	Relevant	Quantifiable	Consideration in the Study
Avoided Energy Generation	Yes	Yes	Yes	Yes	**Considered; Quantified**
Generation Capacity	No	No	No	No	**Not Considered**
Environmental / RPS Compliance	Yes	No	Yes	Yes	**Not Considered**
DRIPE	Yes	Yes	Yes	Yes	**Considered; Quantified**
Ancillary Services	Yes	Yes	Yes	Yes	**Considered; Quantified**
Reserves	Yes	No	No	Yes	**Not Considered**
Transmission and Distribution System Losses	Yes	Yes	Yes	Yes	**Considered; Quantified**
Risk Premium	Yes	Yes	Yes	Yes	**Considered; Quantified**

As Table 1 shows, eight values of solar components can be attributed to the generation or wholesale electricity market. Based on the above parameters, five generation components were included in the analysis:

1. **Energy Generation:** Solar electricity offsets the marginal generation at the wholesale market, reducing the costs associated with the marginal resource(s) in the system.
2. **Wholesale Market Price Suppression or Demand Reduction Induced Price Effect (DRIPE)**: Solar generates electricity, reducing the overall system load. This reduction in system load results in lower market clearing prices, reducing the wholesale electricity price for all customers. Unlike avoided generation, which offsets the amount of electricity produced, DRIPE captures the benefit of lowering prices in the wholesale market. Since ERCOT is an energy-only market, a demand reduction will significantly impact wholesale electricity prices.
3. **Ancillary Services**: Depending on system conditions, this component can be a benefit or cost and may change based on the deployment rate of solar and other resources.[19] Five

[19] National Energy Screening Project. National Standard Practice Manual For Benefit-Cost Analysis Of Distributed Energy Resources. August 24, 2020. https://www.nationalenergyscreeningproject.org/wp-content/uploads/2020/08/NSPM-DERs_08-24-2020.pdf.

ancillary services exist within the ERCOT wholesale market: Regulation Up, Regulation Down, Responsive Reserve Service, Non-Spin Reserve Service, and ERCOT Contingency Reserve Service. Since solar PV is a generation asset and can reduce the need for regulation-up services, the ancillary component only focuses on the regulation-UP benefits.

4. **Transmission and Distribution Line Losses**: Since solar offsets the marginal generation, it avoids the losses that occur as electricity flows through the grid. The value is generally based on the avoided energy costs and is therefore significant, relevant, monetizable, and quantifiable within this study.

5. **Risk Premium:** Retail electricity providers generally incur various market risks when they set contract prices before supply delivery. Solar production reduces the amount of electricity supplied, reducing the market risk to retail electricity providers.

A few generation components were excluded from the analysis, namely:

- **Generation Capacity:** ERCOT is an energy-only market, and unlike other independent system operators, it does not have a capacity market that pays generators to be available to run during high-demand hours.[1] The real-time hourly wholesale electricity prices are meant to capture the actual cost of providing electricity, and thus, this component was not considered relevant in this study.
- **Environmental and RPS Compliance:** Texas established a Renewable Portfolio Standard (RPS) target of 10 GW of installed renewable capacity by 2025 and surpassed it in 2009. Any additional renewable deployment would not add any incremental benefit to its RPS target, which is why this component was not assessed as part of the value stack.
- **Reserves:** In ERCOT, reserves are based on the single largest generator. Although several ancillary services for reserves exist, such as the Responsive Reserve Service, Non-Spin Reserve Service, and ERCOT Contingency Reserve Service, solar is expected not to reduce the overall reserve requirements and may not provide reserve benefits in ERCOT.

Key Solar Characteristics:

- **Annual Production Profile:** The generation components selected for this analysis heavily depend on the annual production capacity factor (kWh per kW) and the shape of the solar production profile. This data was obtained from the National Renewable Energy Lab's PV Watts.[20]
- **Proportion of Solar Exports from Residential Systems:** Determining the portion of solar generation used to power on-site customer load versus exporting back to the grid is important in calculating the distribution line loss factors. For example, distribution line losses could apply to the electricity exported to the distribution grid. As a result, the

[20] National Renewable Energy Laboratory. "PVWatts Calculator". Accessed June 6, 2024. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy.

avoided distribution line loss value would only apply to the portion of the generation consumed at the customer site.

- As seen in Figure 2-2 , the hourly residential load and solar production are matched to determine the portion of self-consumption versus exports.[21,22]

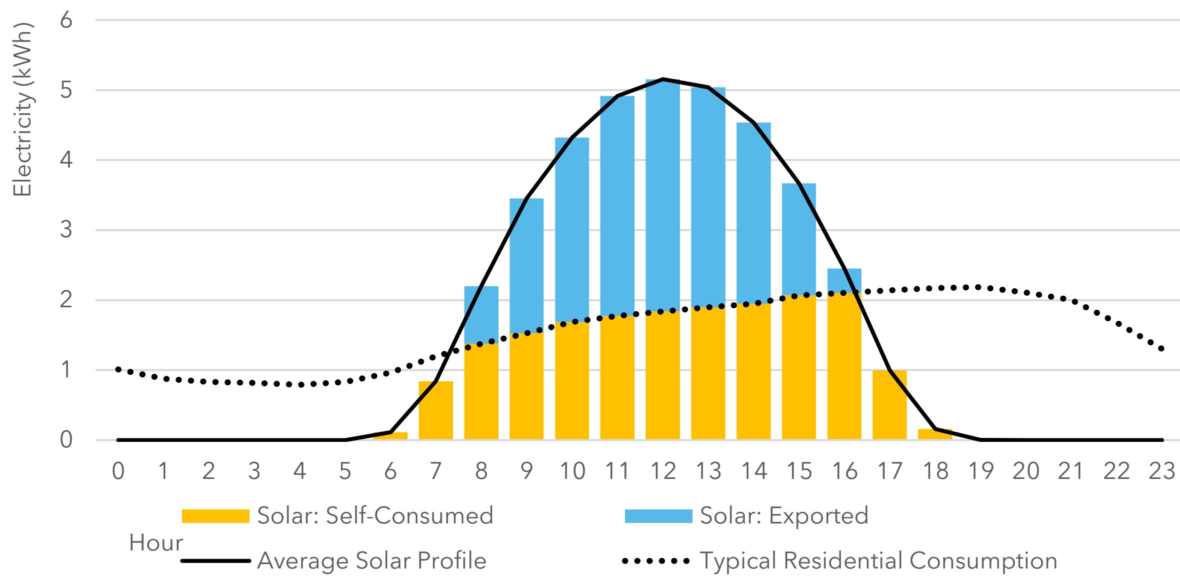

Figure 2-2: Average Residential Solar Customer in Texas

[21] The hourly residential load profile was sourced from the National Renewable Energy Laboratory's ResStock dataset, which provides a sample load profile for Texas. It is important to note that this profile may not represent all residential customers in Texas, as consumption profiles can vary among individual households. Furthermore, the data is from 2021 and may have changed since its release. *Source*: ResStock. 2021. "Public Datasets: End Use Load Profiles for the U.S. Building Stock". National Renewable Energy Laboratory.

[22] The hourly solar production profile was created using NREL's PVWatts tool, combining data from Austin, Dallas, Houston, and Lubbock, Texas. A 9-kW solar PV system was assumed, based on the median system size in Texas in 2022, as reported by the Lawrence Berkely National Laboratory. For more information, see Appendix A.1. Self-consumed solar energy was calculated by assuming that the residential load consumes all generated energy, except when the load is less than the solar output, in which case the excess energy is exported to the grid.

Based on the generation components selected in the previous step, the high-level approach is summarized in Table 2.[23]

Table 2: Approach to Determining Generation Value Components

Generation Components	Approach to Calculating VOS Components
Avoided Energy Costs	The avoided energy costs were developed by mapping the hourly solar production profile against the hourly energy prices obtained from the ERCOT historical Settlement Point Prices (2022-2023).[24] The energy price forecasts were developed using a combination of Short-Term Futures Energy Prices for Texas and EIA Long-Term natural gas price projections.
Wholesale Market Price Suppression (DRIPE)	The wholesale market price suppression benefits (DRIPE) were linked to energy reductions. The Energy DRIPE was developed using the avoided energy costs, applicable price elasticities, and relevant decay factors.[25] We assume these DRIPE benefits would reduce as generation resources and customers respond to lower prices by changing their outputs.
Avoided Ancillary Services	The avoided ancillary costs were developed using historical ancillary service prices in ERCOT. The ancillary price forecast reflects a correlation between ancillary costs and energy prices, meaning ancillary costs rise proportionately with energy cost increases. We assume that solar energy would reduce the regulation UP services procured in the market, thus resulting in an ancillary benefit. For this analysis, the study focused on Regulation Up services.
Transmission and Distribution Line Losses	Avoided line losses were determined using marginal transmission and distribution line loss factors in ERCOT and applied to avoided energy costs. The avoided distribution line losses were limited to the portion of the solar generation that is consumed at the customer site. The avoided transmission line losses were applied to the total generation from the solar PV system.[26]
Risk Premium	After reviewing the existing Value of Solar studies, an appropriate risk premium of 8% was determined for this study. This falls within the range considered suitable by Synapse in AESC study, which spans 5 to 10%.[27] This 8% reflects the additional value solar provides in mitigating price volatility. This risk premium was then multiplied by the avoided energy costs.

[23] Additional details can be found in the Appendix A: VOS Approach
[24] Hourly Energy Data from 2021 was excluded from this analysis. In the 2021 Winter Storm, wholesale energy prices in ERCOT were considerably higher than in other years, leading to an anomaly.
[25] The price elasticities and decay factors were sourced from the AESC 2024 study. We did not develop Texas-specific price elasticities; however, the average price elasticity assumed in this analysis is -1.3, close to the national average price elasticity of -1. The national long-run price elasticities were developed for the 48 states in the US over the 2003-2015 period. Burke, Paul J., and Ashani Abayasekara. "The Price Elasticity of Electricity Demand in the United States." The Energy Journal 39, no. 2 (March 2018): 123-146. https://www.jstor.org/stable/26534427.
[26] The analysis assumed that generation from solar would not be exported into the transmission system.
[27] Synapse Energy Economics. Avoided Energy Supply Components in New England: 2024 Report. Prepared for AESC 2024 Study Group, February 2024. https://www.synapse-energy.com/sites/default/files/inline-images/AESC%202024.pdf.

Delivery Value Components

From the NSPM, Dunsky listed the solar components that apply to the Transmission and Distribution system. Each component was assessed for its significance, monetizability, relevance to the ERCOT system, and whether it could be quantified in this study.

Table 3: Delivery Value Components and their Consideration for Texas' VOS Assessment (based on NSPM).

Utility System Impact	Benefit / Cost	Significant	Monetizable	Relevant	Quanti fiable	Consideration in the Study
Avoided Transmission Capacity	Benefit	Yes	Yes	Yes	Yes	**Considered; Quantified**
Avoided Distribution Capacity	Benefit	Yes	Yes	Yes	Yes	**Considered; Quantified**
Distribution O&M	Benefit or Cost	Possible	Possible	Yes	No	**Considered; Qualitative**
Distribution Grid Support Services	Benefit or Cost	Possible	Possible	Yes	No	**Considered; Qualitative**

As Table 3 shows, four values of solar components can be attributed to the delivery portion of the system, which includes the transmission and distribution system. Based on the above parameters, two delivery components were quantified in the analysis:

1. **Avoided Transmission Capacity:** Based on the coincidence of solar production with the system load profile, the electricity generated from solar can be used to offset a portion of the transmission peak demand. This reduction in transmission peak demand could lower overall system transmission costs.

2. **Avoided Distribution Capacity:** The energy produced by solar PV can avoid or defer distribution capacity upgrade costs if it reduces load at hours associated with reliability concerns (i.e., during peak hours that would otherwise drive investments in distribution system upgrades).

This analysis did not quantify a few distribution-related components that could either be a cost or a benefit to the distribution system:

- **Distribution O&M:** Utilities incur costs to maintain the safe and reliable operation of distribution facilities. This includes the upkeep of substations, wires, and poles and repairing and replacing parts of the distribution system over time. These costs are variable and depend partially on the volume of energy transferred through the system. The electricity generated from solar could result in a cost or avoided cost – reflecting an increase or decrease in costs associated with infrastructure and services

- **Distribution Grid Support Services:** This can be an incurred or avoided cost, representing the increased or decreased costs for distribution system support services needed as solar PV penetration rises. As more solar PV systems are deployed, utilities may face costs to manage voltage issues, while advanced inverter features can handle voltage regulation and offer support services like power factor correction or power quality support, thereby lowering utilities' costs.

Key Solar Characteristics:

- **Valuing Solar's Capacity Contribution to the T&D system:** Effective Load-Carrying Capability (ELCC) is a commonly used measures that captures the contribution of a resource to reliably meeting electricity demand at the times when it's most needed. From a planning perspective, this metric is used to determine solar's capacity contribution the transmission and distribution system. ELCC is typically expressed as a percentage of a resource's capacity; for example, a 100 MW solar plant with an ELCC of 60% could contribute 60 MW to reliability requirements.

The ELCC of a resource is determined based on the cumulative amount of the resource added to the system. As shown in Figure 2-3, as more solar is deployed in ERCOT, solar's capacity contribution will drop from 37% in 2025 to 13% in 2050.[28,29]

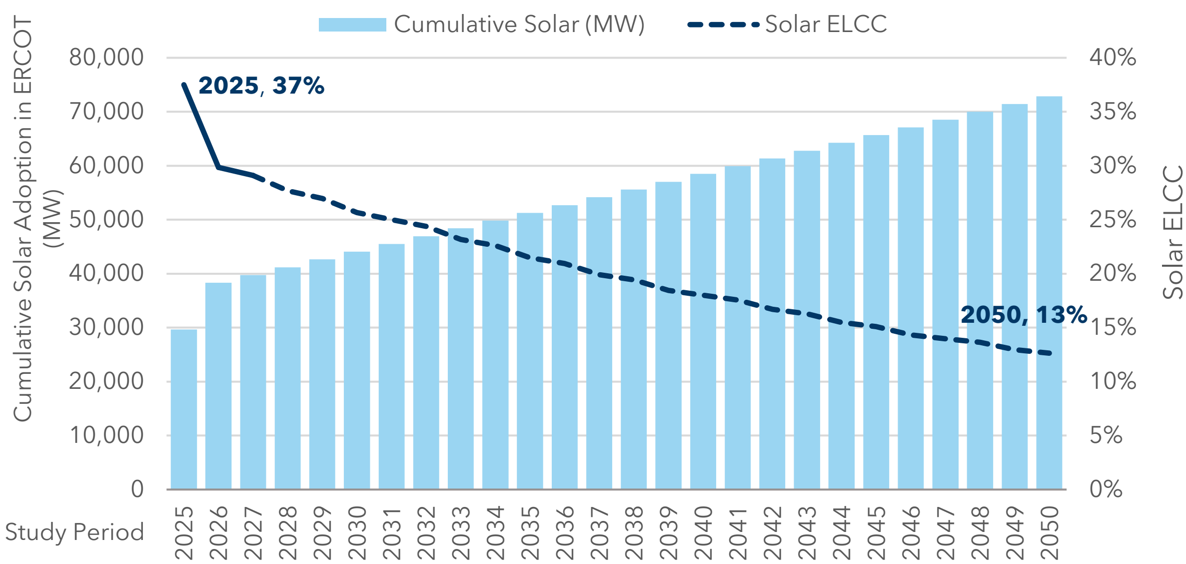

Figure 2-3: ERCOT Effective Load Carrying Capability (ELCC) [30,31,32,33]

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[28] This study calculated the ELCC for the entire portfolio of expected utility-scale solar in the system.
[29] Dunsky's internal analysis estimates that by 2050, an additional 73,000 MW of solar capacity will be installed. According to ERCOT's latest Capacity, Demand, and Reserves (CDR) report, forecasts for utility-scale solar are available for the period from 2024 to 2027, with an expected cumulative installed capacity of 34,705 MW by 2027. After 2027, we anticipate that 1,440 MW of utility-scale solar will be added annually, matching the planned capacity increase for 2027. This is a conservative estimate, and as a result, the total installed capacity by 2050 could be even higher. The 2023 installed capacity was determined by subtracting the 2023 capacity from the 2024 capacity, as reported in the 2022 and 2023 ERCOT CDR reports.
[30] Astrapé Consulting. December 2022. *Effective Load Carrying Study: Final Report*. ERCOT.
[31] ELCC is typically applied to utility-scale systems, however for this analysis, we are using the capacity value from utility-scale systems as a proxy for the capacity value that could be provided from the residential rooftop PV system.
[32] ERCOT. December 2023. *Report on the Capacity, Demand and Reserves (CDR) in the ERCOT Region, 2024-2033*.
[33] National Renewable Energy Laboratory. "PVWatts Calculator". Accessed June 6, 2024. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy.

Based on the delivery components selected in the previous step, the high-level approach is summarized in Table 4.[34]

Table 4: Approach to Determining Delivery Value Components

Delivery Components	Approach to Calculating VOS Components
Avoided Transmission Capacity	ERCOT uses a "postage stamp" rate to cover investments in upgrading and maintaining regional bulk transmission infrastructure.[35] All distribution service providers (DSPs) in ERCOT pay the same rate, based on the total Transmission Cost of Service and their contribution to the ERCOT four-coincident peak (4CP). These costs are passed on to electricity customers assessed annually. We first establish the applicable annual forecast of transmission charges in ERCOT. Next, using the ELCC values established by ERCOT, we determine solar's coincidence with the transmission peak to establish the avoided transmission peak demand. The postage stamp rate was applied to the peak demand reduction to determine the avoided transmission capacity value.
Avoided Distribution Capacity	The energy produced by net-metered solar can avoid or defer distribution capacity upgrade costs if it reduces load at hours associated with reliability concerns (i.e., during peak hours that would otherwise drive investments in distribution system upgrades). Due to the lack of system-wide distribution capacity values for solar, we leveraged existing studies to determine and establish an appropriate distribution capacity value for solar.

[34] Additional details can be found in the Appendix A: VOS Approach

[35] ERCOT Regional Planning. February 2021. *Consideration of the Appropriate Economic Measure for Evaluating Transmission Project in ERCOT.*

Public Value Components

Seven value components could be considered a public benefit based on the NSPM, as shown in Table 5. Two were quantified, while the remaining were considered and qualitatively assessed in the study.[36]

Table 5: Public Value Components and their Consideration for Texas' VOS Assessment (based on NSPM).

Utility System Impact	Benefit / Cost	Significant	Monetizable	Relevant	Quantifiable	Consideration in the Study
Resilience	Benefit or Cost	Possible	Possible	Possible	No	**Considered; Qualitative**
GHG Pollution Reduction Benefit	Benefit	Yes	No	Yes	Yes	**Considered; Quantified**
Economic and Jobs	Benefit	Possible	Possible	Possible	Yes	**Considered; Qualitative**
Air Pollutant Reduction Benefit	Benefit	Yes	No	Yes	Yes	**Considered; Quantified**
Low-Income: Society	Benefit	Possible	Possible	Possible	No	**Considered; Qualitative**
Energy Security	Benefit	Possible	Possible	Possible	No	**Considered; Qualitative**
Reliability	Benefit	Possible	Possible	Possible	No	**Considered; Qualitative**

Based on the above parameters, two public value components were included in the analysis:

1. **GHG Pollution Reduction Benefit:** This component represents the benefits of offsetting the system's marginal pollution, typically natural gas peakers. The reduction benefit is quantified using the EPA Social Cost of Greenhouse Gases.
2. **Air Pollutant Reduction Benefit:** Air pollutants from fossil fuel plants can negatively affect air quality, human health, and ecosystem health. Solar generation can offset a portion of these air pollutants, providing a societal benefit.

Key Solar Characteristics:

- **Solar Production Profile:** Since the marginal emission values for ERCOT were developed on an hourly basis, the public value of solar components will be influenced by the annual production capacity factor (kWh per kW) and the shape of the solar production profile.

[36] The qualitative public value components are described in section 3.

The Table 6 below describes the high-level approach used to quantify the GHG and Air Pollution Reduction Benefits of solar:

Table 6: Approach to Determining Delivery Value Components

Public Benefit Components	Approach to Calculating VOS Components
GHG Pollution Reduction Benefits	Developed using the EPA's Federal Social Cost of Greenhouse Gas and forecasted long-run ERCOT marginal pollution.[37] [38]
Air Pollution Reduction Benefits	Developed using the EPA's COBRA tool and forecasted long-run ERCOT marginal pollution.[39]

Caveats and Uncertainty

This study evaluates the value components by applying assumptions based on the best available information at the time of writing. Therefore, the value of solar may change due to evolving market conditions, policy changes, technological advancements, and updated inputs and assumptions. Additionally, this study aimed to establish a blended average for solar values across ERCOT. In reality, some of the values referenced in this analysis, particularly those related to the transmission and distribution systems, are highly dependent on the location of behind-the-meter solar systems and which part(s) of the electricity system they impact. In Appendix A: A.10 Potential Sources of Uncertainty, we highlight some of the key uncertainty and risk factors that impact the Generation, Transmission, and Distribution components considered in the study.

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[37] National Renewable Energy Laboratory. 2023. "Long-run Marginal Emissions Rates for Electricity – Workbooks for 2023 Cambium Data". Accessed June 6, 2024. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy.

[38] U.S. Environmental Protection Agency. EPA REPORT ON GREENHOUSE GAS EMISSIONS AND CLIMATE CHANGE 2023. December 2023. https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf.

[39] U.S. Environmental Protection Agency. "Co-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA)". Accessed June 6, 2024.

3. Value of Solar Results

The Value of Solar (VOS) in Texas can be broken into three broad categories:

- **Generation**: This category captures the value of the entire ERCOT wholesale market. It comprises avoided energy, ancillary benefits, DRIPE, risk premium, and line losses.
- **Delivery (T&D)**: This category captures the value of solar to the system's transmission and distribution portion and includes the avoided transmission and distribution capacity.
- **Public**: The category captures the public value of solar and includes Air Pollutant and GHG Pollutant Reduction Benefits

We conducted an analysis that quantified each of the benefits under these categories to determine the value BTM solar can provide to the ERCOT system in each year over the 2024-2050 period.

As seen in Figure 3-1 solar's monetizable benefits to the generation and delivery portion of the grid remain relatively stable over time at $0.14/kWh. The delivery system benefits declines over the study period due to solar's declining capacity value. However, the overall value recovers from a minor dip in 2026-2031, driven by increasing gas prices and avoided energy costs.

When considering the societal value, solar shows an even higher overall value, particularly in the early years when the ERCOT marginal pollution is high, and electricity from solar can displace higher emission and pollution sources of generation. The VOS is expected to decrease from $0.27/kWh in 2025 to $0.18/kWh in 2050. This decline is attributed to the increasing proportion of renewable energy in the ERCOT system and the shift of peak demand to later in the day, partly due to behind-the-meter (BTM) solar installations. As a result, BTM solar's capacity to replace marginal gas-fired generation resources is reduced.

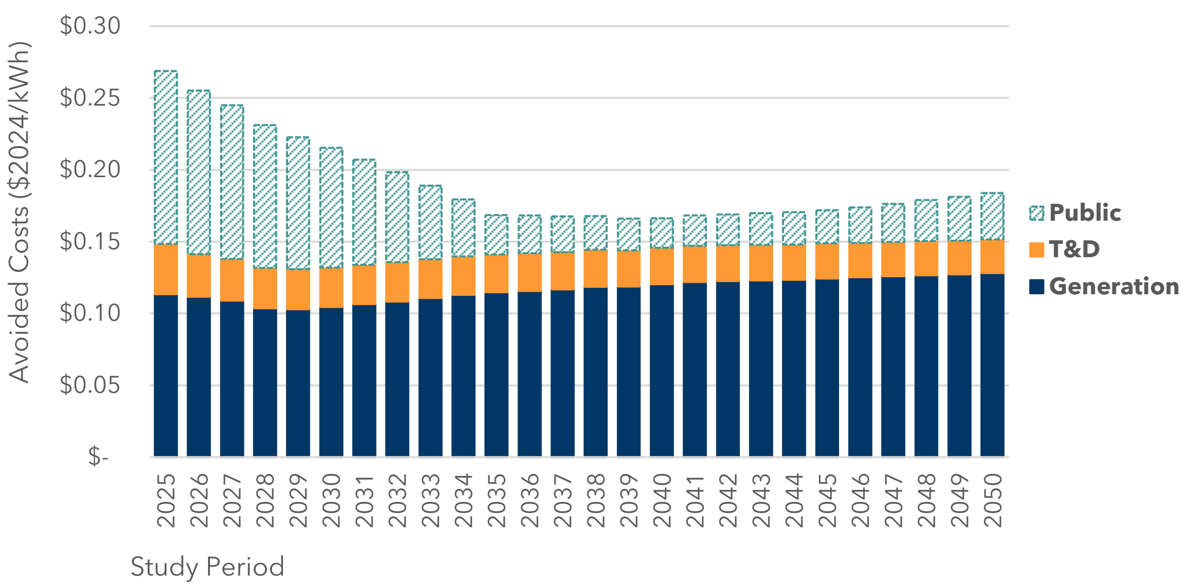

Figure 3-1: Value of Solar in Texas by Component, 2025 to 2050

The generation components represent approximately 60% of the overall value of solar in Texas, followed by the public value (approximately 25%) and the value of the T&D delivery (approximately 15%). Despite component variations, the VOS remains relatively stable across the study period.

The values above present ERCOT-wide averages; however, the analysis shows a variation in the value solar can provide depending on its location within the ERCOT system. The value of solar in the West load zone of ERCOT is higher than the other three zones. This is driven primarily by regional differences in wholesale energy prices and solar generation potential. Considering the North, Houston, South, and West ERCOT Load Zones, the average regional variation represents $0.01 per kWh. As seen in Figure 3-2, the VOS ranges from $0.26/kWh to $0.27/kWh across the four zones.

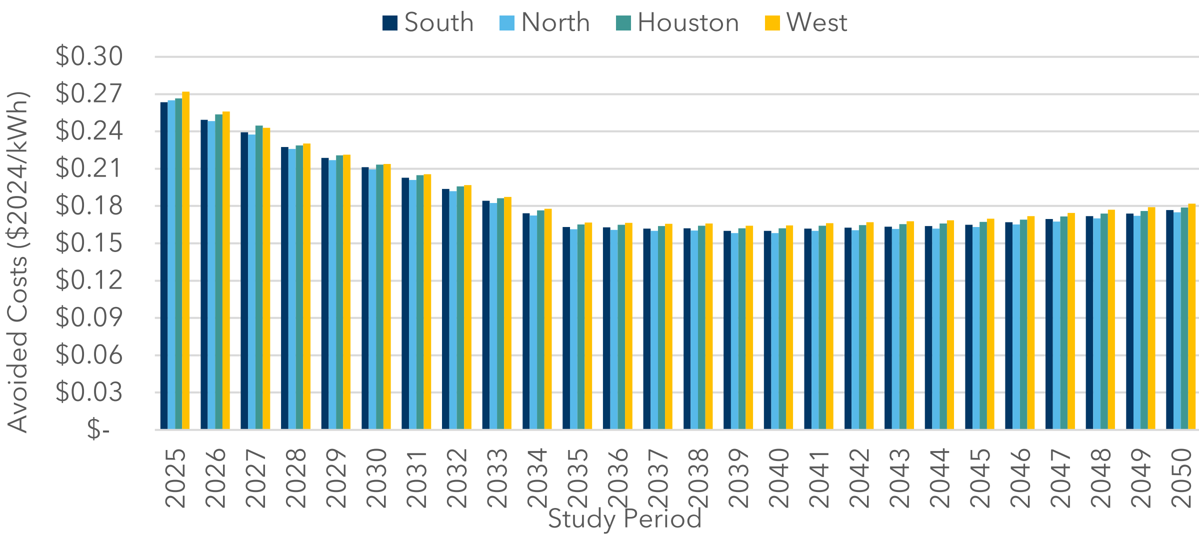

Figure 3-2: Variation in Value of Solar by ERCOT Load Zone, 2025 to 2050

Generation Value

The generation portion of the Value of Solar (VOS) in Texas includes Avoided Energy, Ancillary Benefits, Demand Reduction Induced Price Effect (DRIPE), Risk Premium, and Transmission and Distribution (T&D) Line Losses.

Over the study period, generation accounts for approximately 61% of the total VOS (including public value), valued at $0.12/kWh (2024 dollars), as seen in Figure 3-3 . These values represent a weighted average across ERCOT's North, Houston, South, and West zones, accounting for regional variations in wholesale energy prices and solar generation.

The average value of generation components across the study period are:

Table 7: Generation Components

Generation Component	Average Value ($2024/kWh) 2025 to 2050	Proportion of Total Generation
Avoided Energy Costs	$0.09	78%
DRIPE	$0.01	9%
Risk Premium	$0.01	6%
T&D Line Losses	$0.01	6%
Ancillary Services	$0.0001	0%

As seen in the Figure 3-3, the total value of the generation components remains relatively stable across the study period. Ancillary, DRIPE, Risk Premium, and Line Loss avoided cost components are a function of wholesale energy costs; these components will follow similar trends as wholesale energy costs. If wholesale energy costs increase in the future due to natural gas price spikes, the avoided costs from these components are likely to increase as well. The following sections provide a closer examination of each component.

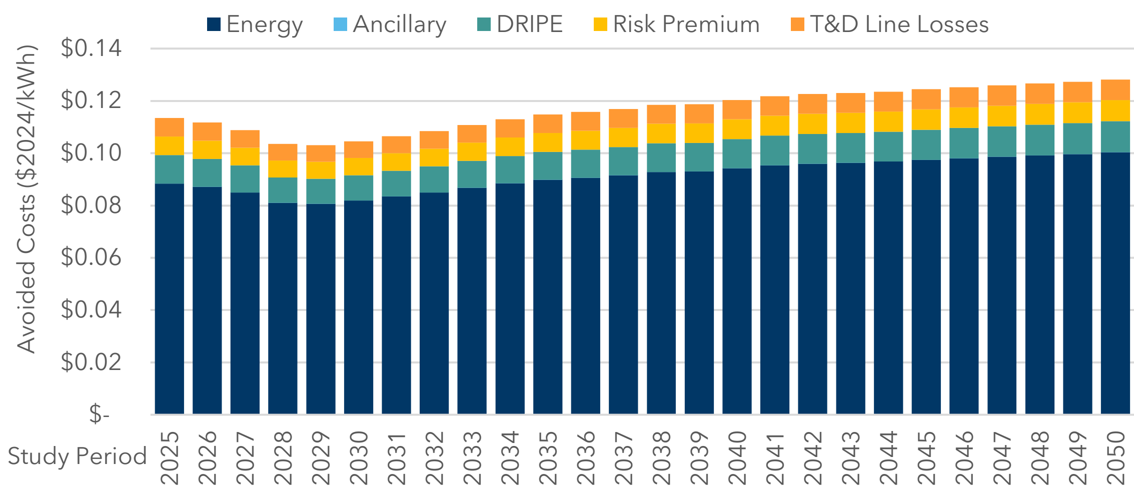

Figure 3-3: Generation Value of Solar in Texas by Avoided Cost, 2025 to 2050

Avoided Energy

The avoided energy benefits in the ERCOT territory range from $0.08/kWh to $0.10/kWh, averaging $0.09/kWh from 2025 to 2050 in real 2024 dollars. Key factors contributing to avoided energy benefits include:

- **Seasonality:** As shown in Figure 3-4, due to high cooling demands in Texas's buildings, the average wholesale energy price in ERCOT is notably higher in summer than in winter, corresponding to the times of highest solar production.
- **Higher Coincidence:** As seen in Figure 3-4, the stronger coincidence between solar insolation and average wholesale energy prices in summer results in higher average avoided energy costs for solar compared to the average wholesale energy price.[40][41]
- **Shifting Peak:** Wholesale energy prices in summer are rising and shifting toward evening periods. This shift in system peak could result in lower avoided energy costs for solar.[42]

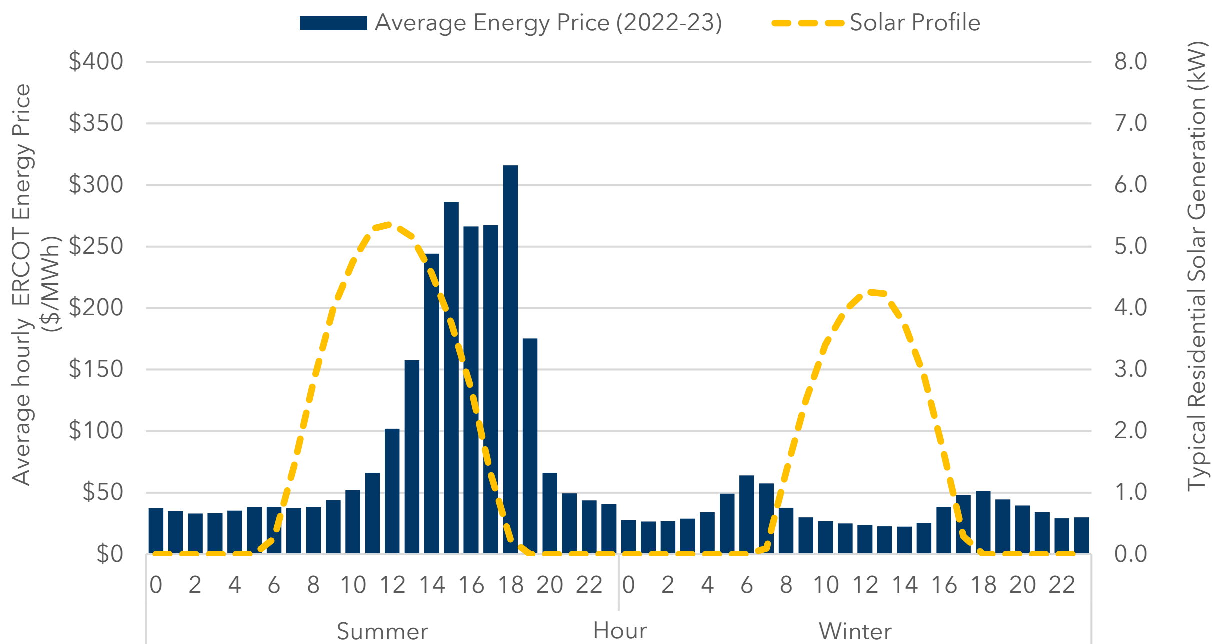

Figure 3-4: Relationship Between Hourly ERCOT Energy Price and Solar Generation Profile

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[40] In 2021, the higher wholesale energy prices during winter, caused by Winter Storm Uri, significantly increased energy prices and avoided energy costs. However, as most of the high-price hours occurred outside of solar insolation periods, the average avoided cost for solar was lower than the average energy price.

[41] Increasing electrification of transportation loads I expected to push the system peak into the evening periods. Solar PV systems that face South-West could technically capture the high avoided energy costs, albeit at a lower generation potential compared to South facing systems.

[42] This study does not account for a shift in system peak across the study period.

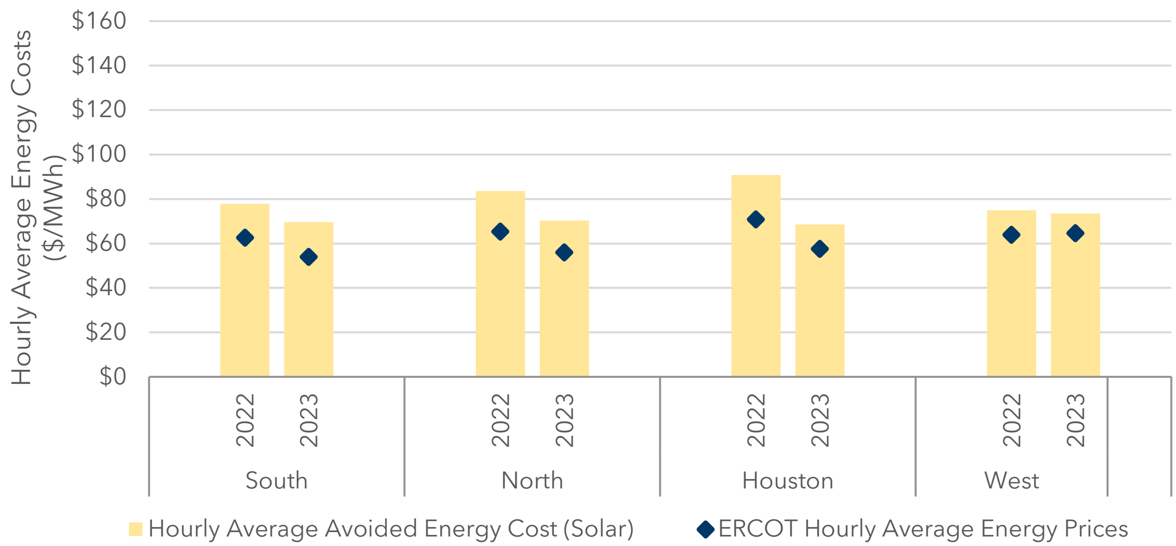

Figure 3-5: Avoided Solar Energy Costs Compared to ERCOT Average Energy Prices

As seen in Figure 3-5, the average avoided energy value of solar energy is somewhat higher than the average ERCOT energy price because solar generation partially offsets energy demand during some of the highest-priced hours of the year. Over the study period, average Avoided Energy costs increased from $0.09/kWh to $0.10/kWh, in real 2024 dollars, driven by rising natural gas spot prices. Wholesale energy prices depend on the marginal generation unit needed to meet grid demand, typically natural gas in ERCOT. As natural gas prices are projected to rise in the short and long term, Avoided Energy costs follow this trend, as shown in Figure 3-6.[43]

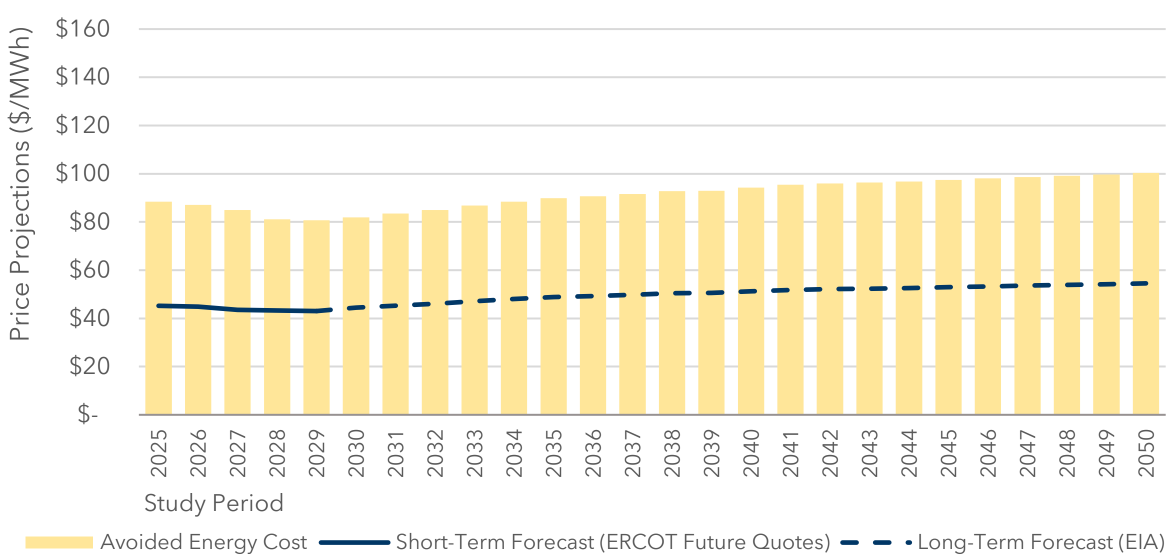

Figure 3-6: Projected Energy Price Forecast and Avoided Energy Costs, 2025-2050

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[43] U.S. Energy Information Administration. 2023. *Table 3. Energy Price by Sector and Source*.

Wholesale Market Price Suppression (DRIPE)

The Demand Reduction Induced Price Effect (DRIPE) benefit from solar in the ERCOT territory averages $0.01/kWh from 2024 to 2050 in real 2024 dollars. DRIPE benefits are typically impacted by:

- **Portion of demand purchased on the energy spot market:** In a typical wholesale electricity market, supply offers are stacked from the lowest to the highest, called the economic merit order. The last supply bid that meets demand sets the market clearing price. Solar generated on the customer side can potentially displace the last supply bid and lower the market clearing price, creating the price suppression benefit. The greater the portion of the energy purchased through wholesale electricity markets rather than through bilateral contracts, the greater the price suppression impact from the demand reduction. However, in ERCOT, the load is not fully exposed to these real-time prices to the extent that load-serving entities (LSEs) may bilaterally contract for supply ahead of the real-time market.[44] As seen in Figure 3-7, on average, about 20% of the load is exposed to real-time prices.[45]

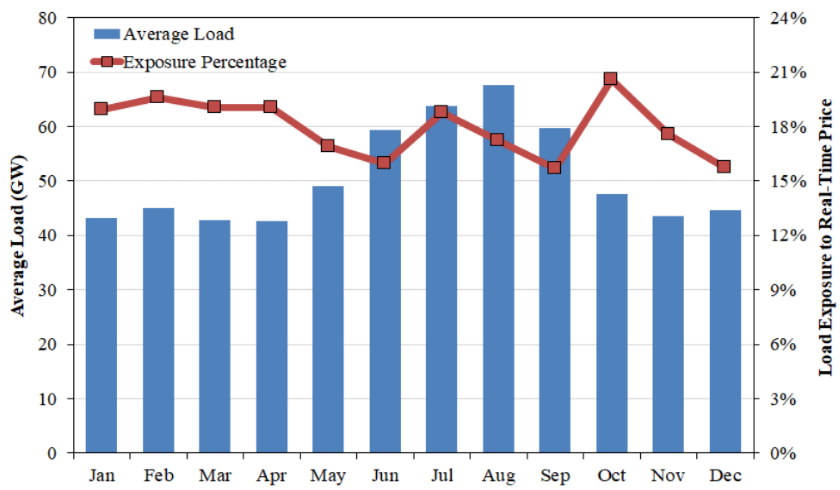

Figure 3-7: Monthly Average Load Exposure in 2022

- **Regional Scope**: ERCOT is an energy-only market, and this analysis assumes that about 20% of the overall demand/retail supply is purchased on the energy spot market. Additionally, this analysis focuses on the entire deregulated ERCOT territory, where 75% of the load comes from competitive-choice customers. Thus, ERCOT's energy and retail choice market is more likely to be impacted by DRIPE.[46]

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[44] In ERCOT, Market participants often purchase their load ahead of ERCOT's Day-Ahead and Real-Time Markets. These purchases occur through bilateral contracts, which occur outside of the ERCOT-administered markets. In these bilateral arrangements, Load Serving Entities and generators may exchange electricity or rights to generating capacity under mutually agreeable terms for a specified period of time. By securing some or all of their projected load demand in advance, companies hope to hedge against potential volatility in the ERCOT Day-Ahead and Real-Time Markets. Source: ERCOT. Market Structure: An Overview of ERCOT and the Texas Nodal Market. September 17, 2019. https://www.ercot.com/files/docs/2019/09/17/Market_Structure_OnePager_FINAL_Revised.pdf.

[45] Potomac Economics. 2023 State of the Market Report for the ERCOT Electricity Markets. May 2024. https://www.potomaceconomics.com/wp-content/uploads/2024/05/2023-State-of-the-Market-Report_Final.pdf.

[46] ERCOT. May 2024. *Fact Sheet: May 2024*.

Ancillary, Risk Premium, and T&D Line Losses

The remaining three generation components contributing to the VOS in the ERCOT territory are Avoided Ancillary Costs, Risk Premiums, and Line Losses. As shown in Figure 3-8, these components further enhance the overall value by addressing specific cost savings and efficiency gains associated with solar generation. Since these components were based on energy costs, they will follow the same trends as avoided energy.

- **Avoided Ancillary Costs:** These costs represent savings from Regulation Up services and account for approximately 10% of avoided energy costs.[47] As seen in Table 8, the Regulation Up makes up only a small portion of the total ancillary costs.[48] The average Avoided Ancillary Cost from 2024 to 2050 is less than $0.0001/kWh. Solar is not a dispatchable asset, but it could reduce the amount of regulation UP services procured during solar insolation hours. [49] In the figure below, avoided ancillary costs on a per MWh basis are marginal.

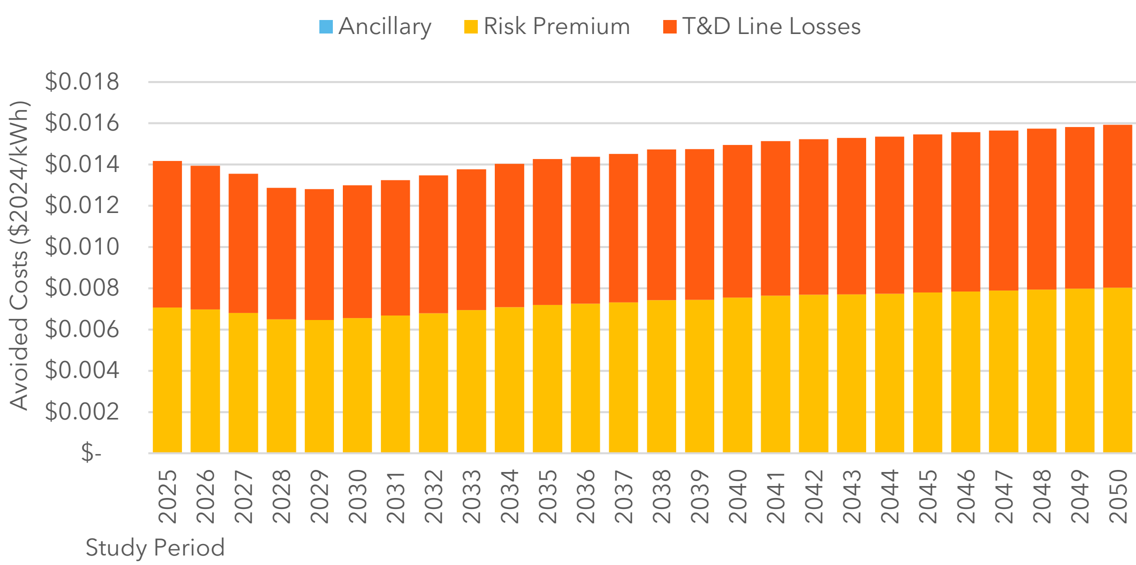

Figure 3-8: Ancillary, Risk Premium, and T&D Line Loss Value of Solar in Texas, 2025 to 2050

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[47] This analysis focuses solely on Regulation Up services. In ERCOT, reserve requirements are based on the single largest generator, which means that solar is unlikely to reduce overall reserve requirements and therefore does not provide reserve benefits. In addition, solar cannot provide an immediate reduction in generation, so Regulation Down services are not considered. However, solar can still contribute to reducing the need for Regulation Up services by decreasing the load on the grid.

[48] Data from 2021 was excluded from the avoided ancillary costs calculations and was considered an outlier due to Winter Storm Uri.

[49] Regulation Service is capacity that can be deployed every 4 seconds to maintain frequency (i.e. balance supply & demand) between 5-min dispatch intervals. It comprises of two different products, regulation Up and Down. Source: ERCOT. ERCOT Methodologies for Determining Minimum Ancillary Service Requirements: 2022. December 2, 2021. https://www.ercot.com/files/docs/2021/12/02/18_2022_ERCOT_Methodologies_for_Determining_Minimum_AS_Requirements.pdf.

Table 8: Historical ERCOT Average Annual Ancillary Services Prices[50,51,52]

	2020 ($/MWh)	2021 ($/MWh)	2022 ($/MWh)	2023 ($/MWh)
Responsive Reserve	$11.40	$331.46	$20.27	24.20
Non-spin Reserve	$4.45	$83.75	$23.29	19.71
Regulation Up	$11.32	$289.84	$25.68	37.34
Regulation Down	$8.45	$120.70	$9.62	17.33

- **Risk Premium**: An 8% risk premium is applied to wholesale energy prices, reflecting the additional value provided by solar in mitigating price volatility. Following the Avoided Energy trend, the average Risk Premium is $0.01/kWh from 2024 to 2050.
- **Line Losses**: Avoided line losses include marginal transmission and distribution losses from solar, with marginal losses being about 1.5 times the average line losses. Transmission line loss benefits apply to the full BTM solar production, while distribution line loss benefits apply only to the self-consumed portion because solar injected into the system will not offset local distribution line losses. Distribution line losses apply only to the portion of the solar that is self-consumed behind the meter, as illustrated in Figure 2-2. The average Avoided Line Losses is $0.01/kWh from 2024 to 2050.

[50] Potomac Economics. May 2023. *2022 State of the Market Report for the ERCOT Electricity Markets*.
[51] Potomac Economics. December 2023. *To the Public Utility Commission of Texas: ERCOT Wholesale Electricity Market Monthly Report*.
[52] These prices represent the ancillary prices per MWh of ancillary product. However, to arrive at avoided ancillary cost per MWh of load, the ratio of the ancillary cost per MWh load to the ancillary service cost was obtained and applied to the applicable avoided ancillary costs.

Delivery Value

The delivery portion of the VOS in Texas includes Avoided Transmission Capacity Costs and Avoided Distribution Capacity Costs. As shown in Figure 3-9, delivery accounts for about 14% of the overall value of solar, equating to approximately $0.03/kWh across the study period (in real 2024 dollars).

Table 9: Delivery Components

Delivery Component	Average Value ($2024/kWh) 2025 to 2050	Proportion of Total Delivery
Avoided Transmission Capacity Costs	$0.01	70%
Avoided Distribution Capacity Costs	$0.01	30%

Over the study period, the average delivery value decreases from $0.03/kWh to $0.02/kWh. This forecast is based on solar's Effective Load Carrying Capability (ELCC), which drops from 37% to 13% as the cumulative solar capacity on the ERCOT system increases, as shown in Figure 3-10.[53,54]

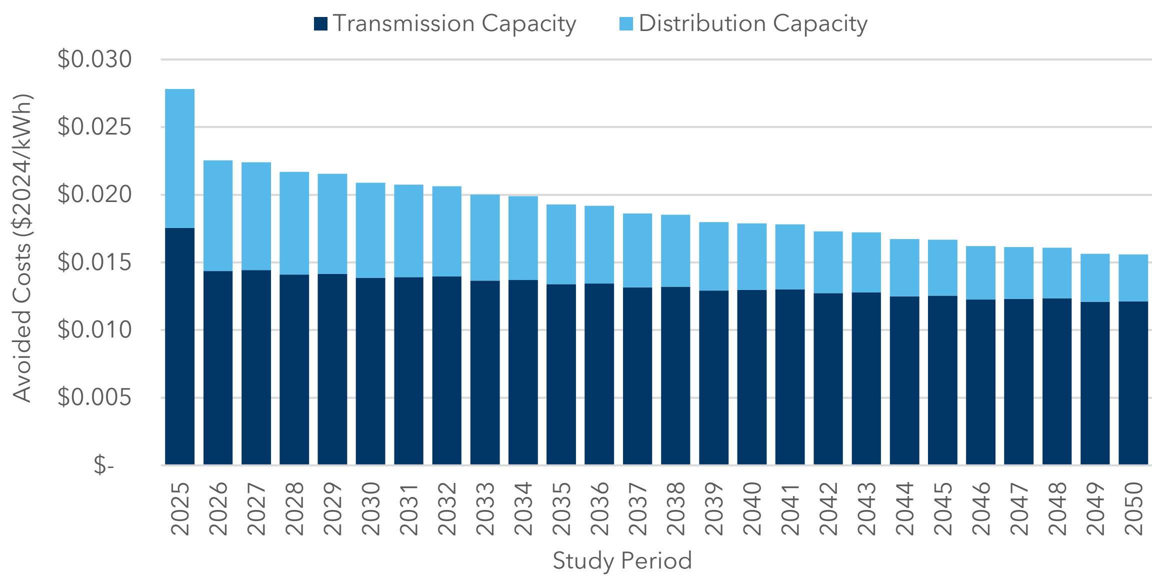

Figure 3-9: Delivery Value of Solar in Texas by Avoided Cost, 2025 to 2050

Solar's ELCC represents its ability to contribute to reliability requirements. It decreases as more solar capacity is added and the portion of the solar generation that coincides with the system demand peaks is reduced. This phenomenon means that each additional solar installation contributes less to avoiding transmission and distribution capacity costs.

[53] Astrapé Consulting. December 2022. *Effective Load Carrying Study: Final Report*. ERCOT.
[54] ERCOT. December 2023. *Report on the Capacity, Demand and Reserves (CDR) in the ERCOT Region, 2024-2033*.

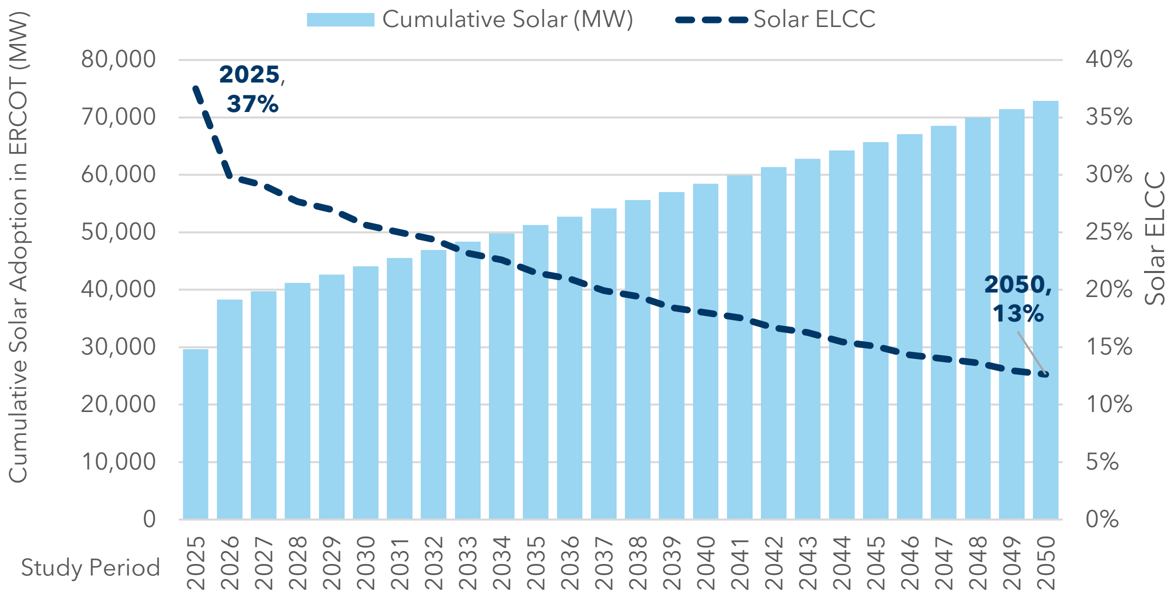

Figure 3-10: Relationship Between Cumulative Solar Capacity in ERCOT and Solar ELCC, 2025 to 2050

ELCC is typically expressed as a percentage of a resource's capacity. For example, a 100 MW solar plant with an ELCC of 60% could contribute 60 MW to reliability requirements. As the cumulative solar capacity grows, the ELCC of solar drops, and the marginal value of T&D capacity decreases over time. Therefore, as solar's ELCC decreases, its avoided transmission and distribution capacity value decreases throughout the study period.

Avoided Transmission Capacity

The average Avoided Transmission Capacity value across the study period is $0.01/kWh, slightly decreasing from $0.02/kWh to $0.01/kWh.[55] The value depends on two main factors:

- **ERCOT's Transmission Charge**: ERCOT uses a "postage stamp rate" to recoup transmission investment costs. The "postage stamp rate" paid by distribution service providers (DSPs) to recover transmission investment costs, is forecasted to increase by about 1% annually (real), as shown in Figure 3-11.[56,57] All DSPs in ERCOT pay the same rate, calculated based on their contribution to the ERCOT 4CP.[58] As seen in Figure 3-12, the transmission charge imposed by ERCOT is similar to NYISO (ConEd) and PJM but lower than ISO-NE and PJM (AEP).

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[55] The avoided transmission capacity costs were calculated on a $/kW basis; however, to convert into a $/kWh basis, the overall transmission avoided costs were distributed over the total solar production.
[56] ERCOT. February 2021. *Consideration of the Appropriate Economic Measure for Evaluating Transmission Projects in ERCOT*.
[57] The rate of increase in transmission charges may be higher than 1% if the projected demand for energy increases according to recent ERCOT projections. Using the historical rate of change is a conservative assumption.
[58] In the ERCOT (Electric Reliability Council of Texas) context, "4CP" stands for Four Coincident Peak. It refers to the four highest system-wide demand intervals in June, July, August, and September. These peaks are used to determine customer transmission charges based on their usage during these intervals. The 4CP methodology incentivizes customers to reduce their demand during peak periods to lower their transmission costs.

- **Transmission Capacity Contribution**: Solar's ELCC is used as a proxy for avoided transmission capacity and is expected to decrease over the study period as more solar gets added to the system. Increasing solar deployment will reduce the overall capacity value that solar can provide to the system peak.

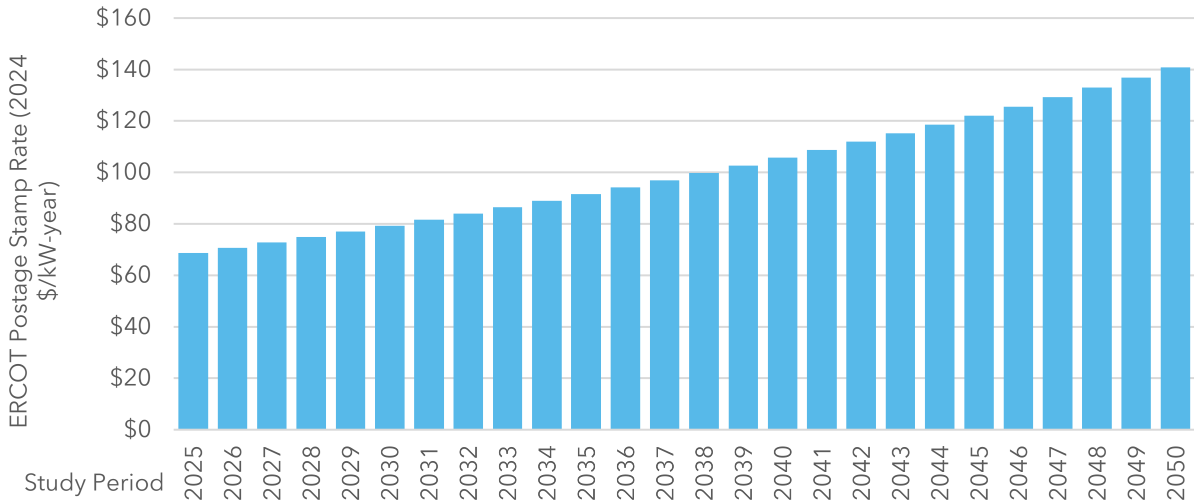

Figure 3-11: Forecasted ERCOT Postage Stamp Rate (Transmission Charges), 2025 to 2050

The cumulative effect of an increasing transmission charge and a declining ELCC value leads to an overall decrease in the Avoided Transmission Capacity benefits over the study period. This conservative approach may underestimate potential increases in regional transmission charges due to widespread electrification and renewable build-out, as tends in historical ERCOT postage stamp rates may not fully reflect the significant electrification expected over the study period. In addition, this analysis does not account for any potential shift in 4CP hours, which may decrease the coincidence factor for BTM solar over time.

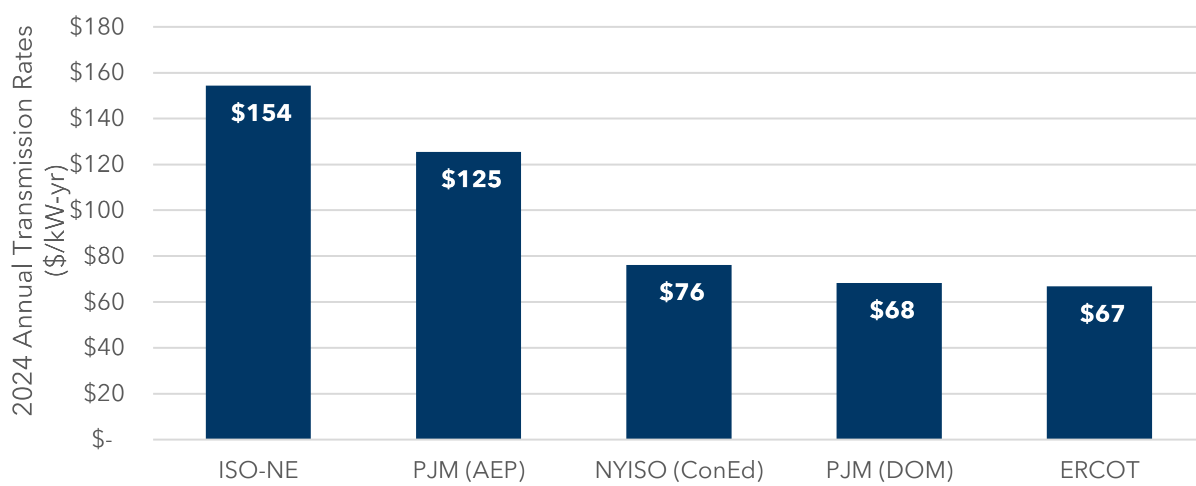

Figure 3-12: Annual Transmission Rates by ISO/RTO in 2024

Avoided Distribution Capacity

The average Avoided Distribution Capacity value across the study period was $0.01/kWh, but it significantly decreases to less than $0.01/kWh.

This study uses a proxy value for the distribution capacity costs based on other value of solar and distributed resource studies, as seen in Figure 3-13. While distribution capacity upgrade deferral is assumed to remain flat, the declining ELCC value results in a continuous decrease in Avoided Distribution Capacity value over the study period.

The avoided costs assumed in this study represent statewide values. However, solar's distribution value can vary across feeders and substations. A more granular locational study would be necessary to develop a localized distribution capacity value for solar in ERCOT.

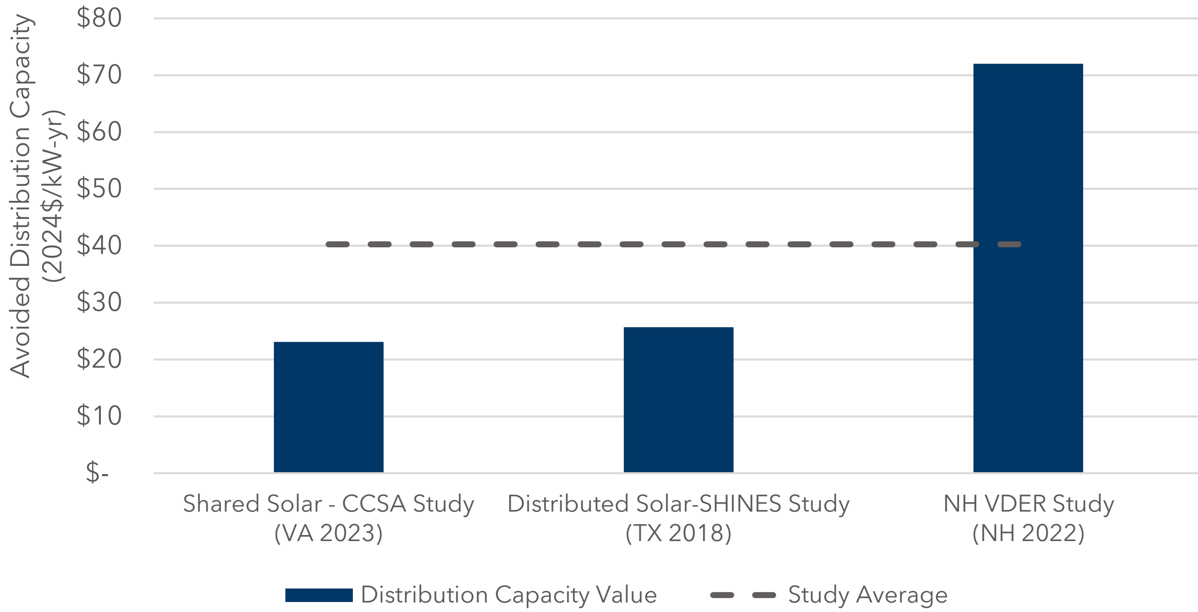

Figure 3-13: Average Avoided Distribution Capacity Costs Across Studies

Public Benefits

As shown in Figure 3-14, public benefits contribute approximately 25% of the overall value of solar in Texas, averaging $0.05/kWh across the study period in real 2024 dollars. These benefits consist of GHG Pollution Reduction Benefits and Air Pollution Reduction Benefits. These benefits may not be monetizable but they are important to consider to assess the societal value that solar offers to all Texans.

GHG Pollution Reduction Benefits constitute about 90% of the overall public avoided costs, followed by Air Pollutant Reduction Benefits at approximately 10%. Throughout the study period, the average public benefits range from $0.12/kWh to $0.02/kWh.

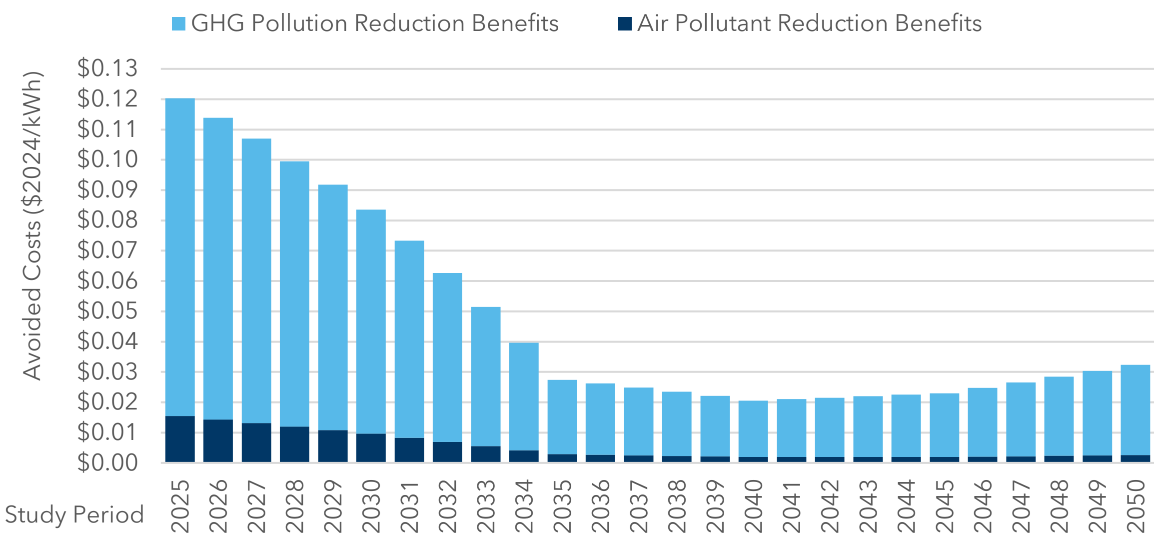

Figure 3-14: Societal Value of Solar in Texas by Avoided Cost, 2025 to 2050

The average value of the public components across the study period are:

Table 10: Delivery Components

Public Component	Average Value ($2024/kWh) 2025 to 2050	Proportion of Total Public
GHG Pollution Reduction Benefit	$0.04	90%
Air Pollutant Reduction Benefit	<$0.01	10%

Greenhouse Gas Pollution Reduction Benefits

The average GHG Pollution Reduction Benefit value across the study period is $0.04/kWh. Starting at $0.10/kWh, it declines significantly in 2040 to $0.02/kWh before increasing to $0.03/kWh by 2050.

The overall Reduction Benefit depends on two key factors:

- **Marginal Pollution Rates:** Forecasted marginal pollution rates in ERCOT, including CO_2, CH_4, and N_2O.[59]
- **Social Cost of Greenhouse Gases (SC-GHG):** The estimated social cost of greenhouse gases from 2025 to 2050.[60]

As illustrated in Figure 3-15, in the long term, ERCOT's marginal GHG pollution rates are expected to decline significantly during solar insolation hours, leading to reduced GHG Pollution Reduction Benefits due to lower pollution. Increasing solar and wind deployment will largely drive this reduction in Texas's marginal pollution. However, from 2040 to 2050, benefits increase slightly as marginal pollution rates stabilize while the social cost of GHGs rises significantly due to expected worsening climate damages with increasing atmospheric GHG concentrations.

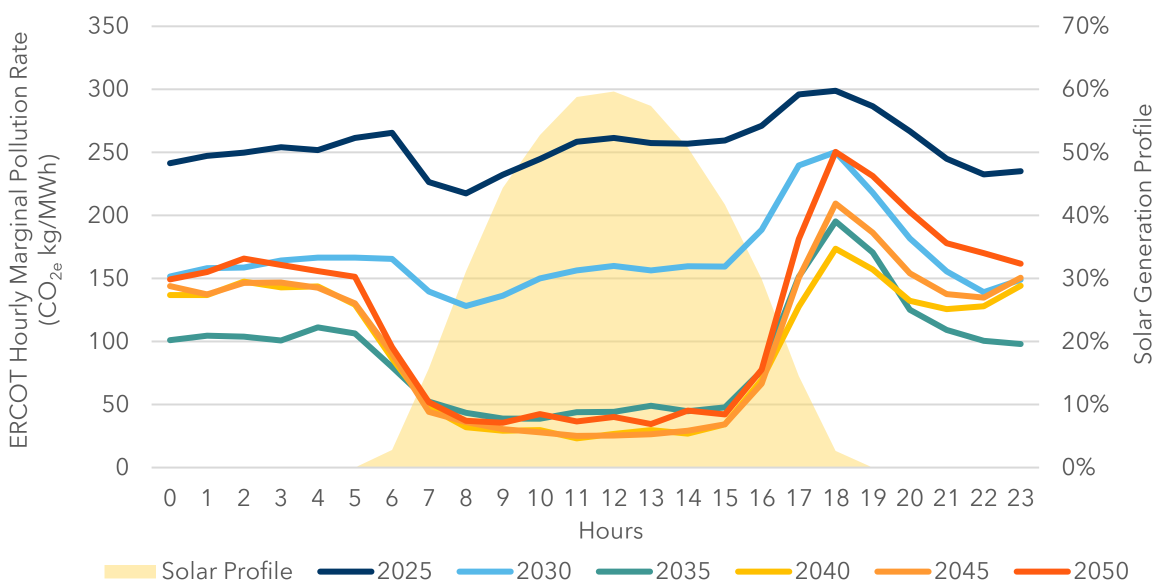

Figure 3-15: Relationship Between Marginal GHG Pollution and Solar Generation Profile, 2025 to 2050

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[59] National Renewable Energy Laboratory. 2023. "Long-run Marginal Emissions Rates for Electricity – Workbooks for 2023 Cambium Data". Accessed June 6, 2024. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy.
[60] U.S. Environmental Protection Agency. November 2023. *Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances*.

As shown in Figure 3-16, throughout the study period, the Societal Cost of GHG (SC-GHG) (including CO2, CH4, and N2O) increased from $403/ton to $693/ton in 2050.

Despite this increase, as the marginal emission reduction benefit from solar decreases, the avoided GHG Pollution Reduction benefits also drop.

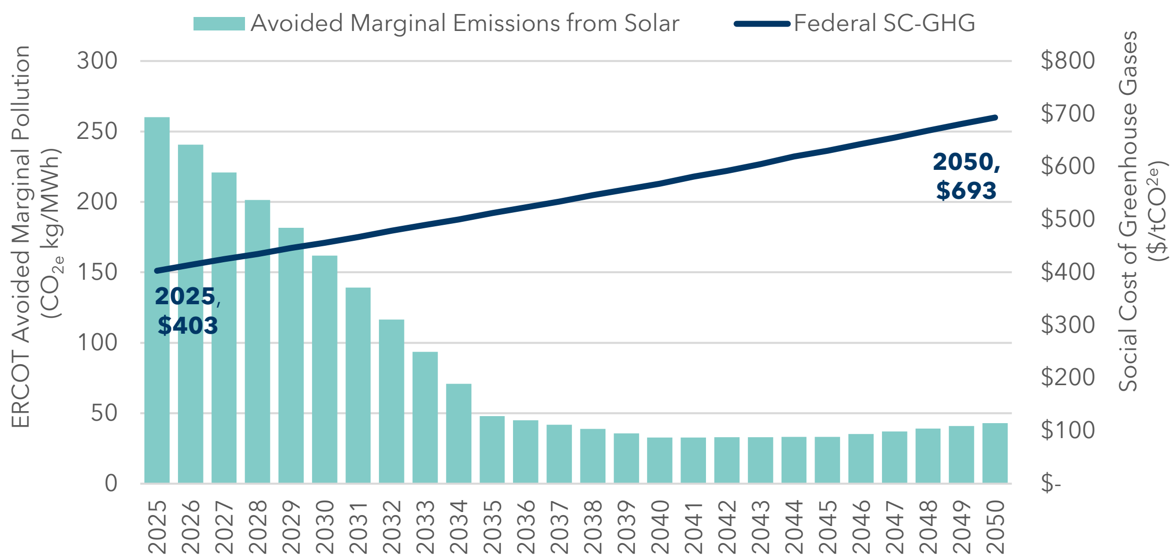

Figure 3-16: Variations Between the Avoided Marginal Pollution from Solar and the Social Cost of Greenhouse Gases, 2025 to 2050

Air Pollution Reduction Benefits

The average Air Pollution Reduction Benefit value across the study period is $0.01/kWh. Starting at $0.02/kWh, it declines to less than $0.01/kWh by 2034.

In the initial study year, the Air Pollution Reduction Benefits are calculated using the EPA's COBRA tool and Texas' current marginal air pollutant rates of NO_x and SO_2.[61,62] This tool estimates the economic value of the health benefits from avoiding air pollution. These benefits are then derated using the forecasted decline in marginal emissions rates for greenhouse gases as a proxy. Similar to GHG Pollution Reduction Benefits, the value declines significantly throughout the study period due to declining marginal pollution rates. However, it increases slightly from 2040 to 2050 due to a slight rise in marginal pollution rates during solar insolation hours over that decade.

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[61] U.S. Environmental Protection Agency. 2022. "eGRID Data Explorer". Accessed June 6, 2024.
[62] U.S. Environmental Protection Agency. "Co-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA)". Accessed June 6, 2024.

Qualitatively Assessed Benefits

Reliability: Distributed solar provides utilities with significant reliability benefits. It helps maintain the stability of the generation, transmission, and distribution systems, enabling them to withstand instability, uncontrolled events, cascading failures, or the anticipated loss of system components.

Resilience: Energy resilience encompasses the capacity of the grid, buildings, and communities to endure power interruptions and swiftly recover while maintaining essential services like electricity, heating, cooling, and ventilation.[63] In this study, "resilience services" are defined as the ability of Distributed Energy Resources (DERs) to provide backup power to a site if it loses utility electricity service.[64] Planning solar PV systems to be microgrid-ready can be a low- or no-cost way to facilitate the installation of equipment required for microgrid applications later.[65] This may include selecting inverters that can interact with the grid or operate in microgrid modes, inverters that are responsive to microgrid controllers, or simply ensuring there is space onsite near the DER installation for additional components in the future. A National Association of Regulatory Utility Commissioners (NARUC) report found previous regulatory proceedings that attempted to value resiliency but were unsuccessful at arriving at a quantified value of resilience services. The report noted that resilience value has been quantified in non-regulated proceedings, but these have been highly context-specific.

Economy and Jobs: While quantifying job benefits in Value of solar assessments is less common and can vary from jurisdiction to jurisdiction, the potential job development of the solar industry in Texas should be considered. The development of the solar industry in the province would create new high-skill jobs, which would result in an expansion in the tax base and the creation of supporting industry roles and benefits that would also make their way to the province and its residents. Based on the Pembina study, **every MW of residential solar installed resulted in an additional twelve to twenty Full-Time Equivalent jobs that year.** [66]

Thus, solar contributes to incremental economic growth and job creation from a public perspective. In addition, solar can bring stable and predictable revenue streams to communities through employee wages and the local supply chain involved in installing and maintaining solar PV systems.

Poverty and Energy Equity: Solar energy addresses environmental justice concerns and can promote poverty alleviation and energy equity. Projects have the potential to uplift marginalized communities by providing increased access to electricity, particularly in remote or underserved areas that lack access to stable, reliable energy grids. By deploying off-grid or microgrid solar systems, communities can become self-sufficient in meeting their energy needs, thus reducing reliance on expensive and unreliable energy sources.

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[63] Office of Energy Efficiency and Renewable Energy. "Energy Resilience". U.S. Department of Energy. Accessed June 6, 2024.
[64] This definition was sourced from the U.S. DOE Office of Energy Efficiency and Renewable Energy, available online: https://www.energy.gov/eere/femp/distributed-energy-resources-resilience.
[65] NREL. (2017). Microgrid-Ready Solar PV – Planning for Resilience. Available online: https://www.nrel.gov/docs/fy18osti/70122.pdf.
[66] Microsoft Word - Job growth in clean energy.docx (pembina.org)

4. Excess Credit Value

In their Solar Buyback Plans, non-competitive utilities in Texas offer a wide range of export credits (from 3 ¢/kWh up to 19 ¢/kWh). This disparity in solar compensation exists because utilities have different ways of evaluating the grid benefits from solar. Typically, utilities do not consider solar's additional benefits to the wholesale market, such as avoided risk premium costs, ancillary costs, and price suppression benefits, as well as its benefits to the T&D system in the form of avoided transmission and distribution capacity costs. As a result, these export credits may not accurately reflect the value solar provides to the system.

This study evaluated the overall benefit of a net-metered solar PV system to the Texas grid, focusing on the energy consumed on-site and exported into the grid. The following section provides a high-level assessment of the value of the exported energy from a residential solar PV system.

Figure 4-1 illustrates a hypothetical Net Metered Residential Customer in Texas. The blue bars represent the portion of solar energy self-consumed, while the yellow bars represent the portion of solar energy exported into the grid. This section aims to evaluate the value of the exported portion (i.e., yellow bars) in isolation.

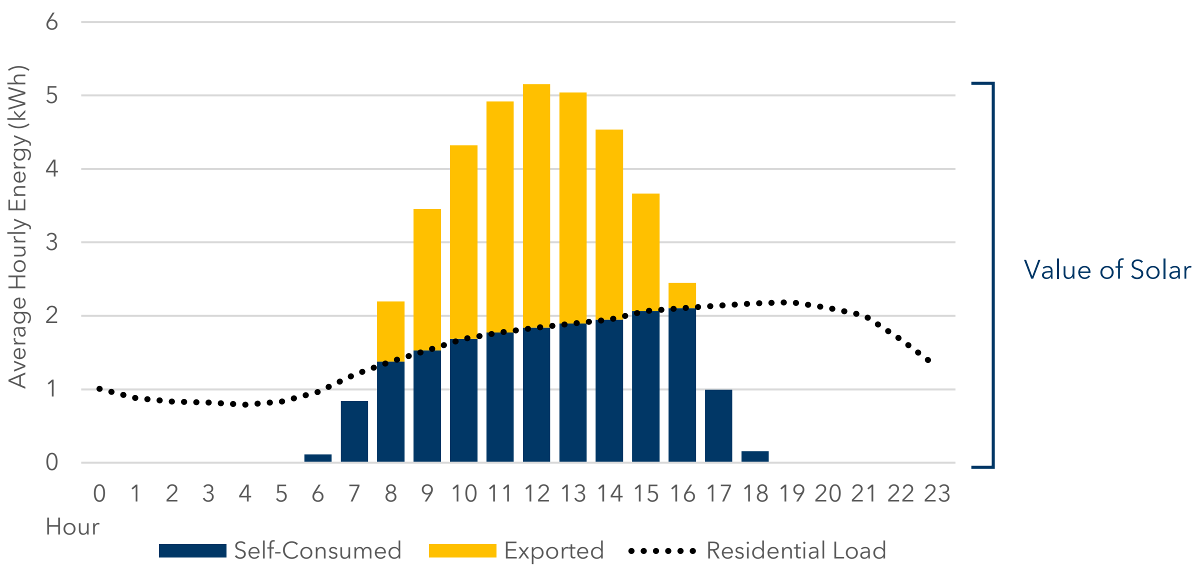

Figure 4-1: Hypothetical Net-Metered Residential Customer in Texas

While this analysis aimed to determine an average Export Credit Value for a typical solar customer, the actual credit value will vary based on an individual customer's consumption profile. Furthermore, the objective of this analysis is not to assign a specific export credit value directly but to establish a generalized value and formula that can reasonably apply to average consumption characteristics among consumers in Texas.

Excess Credit Formula

The first step involved developing a hypothetical generation profile that captures the exports from a typical net-metered residential system, as shown in Figure 4-2.

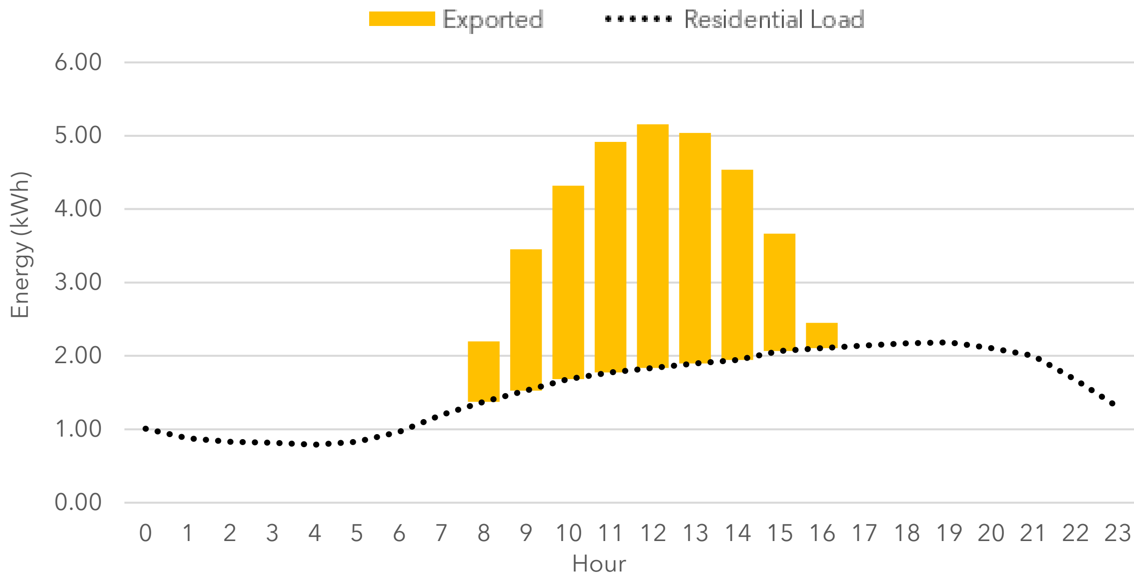

Figure 4-2: Hypothetical Solar Exports from Net-Metered Residential Customer in Texas

The general formula for calculating the Export Credit Rate is based on:

- The Value of Solar (VOS)
- Program administration costs[67]
- The prevailing retail rate (the rate at which self consumed solar generation is currently compensated)
- The proportion of solar generation that is self-consumed versus the proportion exported to the grid

The formula is as follows:

Equation 1: Excess Credit Formula

$$Export\ Credit\ Rate = \frac{(VOS - Program\ Admin) - (Retail\ Rate\ \times Solar\ Self\ Consumed_{\%})}{Solar\ Exported_{\%}}$$

[67] This analysis excludes the impact of utility program administration costs (e.g., interconnection studies, O&M costs), which could lower the net Value of Solar and thus reduce the export credit rate. In this equation, the program admin costs would ideally be expressed on $/kWh basis.

Application of Excess Credit Formula

As illustrated in Table 11: Scenarios and Excess Credit Values, the export credit rate is sensitive to changes in any of the above variables. Two scenarios are presented to demonstrate how the export value would change based on changes in retail rates, the value of solar, and prevailing compensation for self-consumed solar.

Table 11: Scenarios and Excess Credit Values

	Value of Solar	Retail Rate	Excess Credit Rate
Base Case (VOS > Retail Rate)	Assumes all the value stack's monetizable components (generation and delivery). **VOS: $0.14/kWh**	This assumes a **Retail Rate of $0.12/kWh**, and all solar production consumed at the customer site is compensated at the retail rate.	**Excess Credit: $0.16/kWh**
Higher Retail Rate (VOS < Retail Rate)	Assumes all the value stack's monetizable components (generation and delivery). **VOS: $0.14/kWh**	This assumes a **Retail Rate of $0.18/kWh**, and all solar production consumed at the customer site is compensated at the retail rate.	**Excess Credit: $0.11/kWh**

Base Case: The base case represents a scenario in which all the value stack components, including DRIPE, are recognized as system benefits, and the **value of solar is greater than the prevailing retail rate**.[68]

- If the electricity consumed from customer-sited solar were compensated at $0.12/kWh, the solar consumed at the customer site would be compensated lower than its current value to the system.
- Therefore, by applying Equation 1, the export rate compensation would need to increase to $0.16/kWh to ensure that the net compensation for the entire solar production matches its true value to the system ($0.14/kWh).

Higher Retail Rate: This scenario represents the case where all the value stack components, including DRIPE, are recognized as system benefits, and the **retail rate is greater than the value of solar**.[69]

- Under this scenario, electricity consumed from customer-sited solar was compensated at $0.18/kWh; the solar consumed at the customer site would be compensated higher than its current value to the system ($0.14/kWh).
- Therefore, by applying Equation 1, the export rate compensation would drop to $0.11/kWh to ensure that the net compensation for the entire solar production matches its true value to the system ($0.14/kWh).

Thus, the excess credit compensation is highly sensitive to the total value stack and the prevailing retail rates.

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[68] Assumes, Value of Solar (excluding Public Benefits): $0.15/kWh; Self-consumed portion of solar generation: 45%; Exported solar generation: 55%; the retail rate is $0.12/kWh

[69] Assumes, Value of Solar (excluding Public Benefits): $0.15/kWh; Self-consumed portion of solar generation: 45%; Exported solar generation: 55%; the retail rate is $0.18/kWh

Appendix A: VOS Approach

A.1 Energy

A.1.1 Rationale

The electricity generated by solar assets reduces the marginal demand, which in turn reduces the **energy generated by the marginal resource**. This results in avoided energy costs. The decrease in load resulting from solar generation translates to a reduction in energy that would otherwise be generated and procured through the ERCOT wholesale energy market.

A.1.2 Methodology

Step 1: Develop Zonal Solar Generation Profiles

- Using PV-Watts, a solar generation profile was developed for Dallas, Houston, Austin, and Lubbock.[70] These regions were chosen due to their high residential density, which results in solar generation profiles that accurately represent a significant portion of Texas' population.
- The variations in generation profiles by city represent the low and high bounds of solar generation in the ERCOT region, with average capacity factors calculated for each region.

Step 2: Establish the Historical Avoided Energy Costs

- Within the ERCOT wholesale market, thirteen load zones exist, and four designated Competitive Load Zones – North, West, South, and Houston Load Zones – contain most of ERCOT's load.[71] Energy prices can vary significantly based on location; incorporating historical data from multiple load zones enables the capture of this locational variability. According to ERCOT historical data, the Houston Zone typically has the highest energy costs, while the South Zone has the lowest.[72]
- The hourly Historical Settlement Point Price Data was collected for ERCOT's North, West, South, and Houston Load Zones from 2022 to 2023.
- An annual solar-weighted average energy cost was derived by multiplying hourly avoided energy cost data (SPP) with each region's hourly solar generation profile.

Step 3: Forecast Avoided Energy Costs (2025 to 2050)

- Short Term Forecast (2025-2029): Forward Prices of the respective ERCOT load zones were used to adjust the base year's energy costs and develop short-term forecasts for

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[70] National Renewable Energy Laboratory. "PVWatts Calculator". Accessed June 6, 2024. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy.
[71] Electric Reliability Council of Texas. "Training Courses: Locational Marginal Pricing". Accessed April 24, 2024.
[72] Electric Reliability Council of Texas. "Historical DAM Load Zone and Hub Prices". Accessed June 6, 2024.

avoided energy costs.[73] [74] [75] [76] This approach reflects the future agreed-upon delivery price of electricity.

- Long-Term Forecast (2030 to 2050): The EIA Annual Energy Outlook 2023 was leveraged to develop long-term annual avoided energy cost forecasts.[77]

A.1.3 Inputs, Assumptions, and Notes

Inputs	Sources
Historical Settlement Point Prices	ERCOT Historical DAM Load Zone and Hub Prices
ERCOT Forward Prices	CME Group
U.S. EIA Natural Gas Price Forecast	U.S. EIA Annual Energy Outlook 2023: Energy Prices by Sector and Source
PVWatts Profile	NREL PVWatts: Dallas; Houston; Austin; Lubbock

Assumptions and Notes

- **Choice of Locational Price Data:** The Locational Marginal Price (LMP) in ERCOT reflects the hourly energy cost for each node. However, for this statewide analysis, the historical Day-Ahead ERCOT Load Zone Settlement Point Prices (DAM-SPP) were used as a proxy for avoided energy costs in the region. DAM-SPP represents the load-weighted average of LMPs across load zones and includes price adders for factors such as congestion and losses. These prices also serve as the basis for settling electricity costs for Retail Electric Providers (REPs) and other market participants. Therefore, the SPP provides a more accurate reflection of energy costs across different load zones.
- **Marginal Resource:** This analysis assumes that natural gas generation will be the marginal resource, influencing the avoided energy costs throughout the study period.
- **Line Losses**: Settlement Point Prices exclude line losses.[78]
- **Solar Assumptions:** The PVWatts solar profile yields a 17.2%, 16.8%, 16.2%, and 19.9% average capacity factor for rooftop solar in Dallas, Austin, Houston, and Lubbock. The following resource data site and system info inputs were used:
    - Module type: *Standard*, Array Type: *Fixed (roof mount)*, System Losses: *14.08%*, Tilt: *20 degrees*, Azimuth: *180 degrees*. All advanced parameters were kept as their default inputs.

[73] CME Group. "ERCOT North 345 KV Hub 5 MW Peak Futures – Quotes". Accessed April 24, 2024.
[74] CME Group. "ERCOT Houston 345 KV Hub 5 MW Peak Futures – Quotes". Accessed April 24, 2024.
[75] CME Group. "ERCOT South 345 KV Hub 5 MW Peak Futures – Quotes". Accessed April 24, 2024.
[76] CME Group. "ERCOT West 345 KV Hub 5 MW Peak Futures – Quotes". Accessed April 24, 2024.
[77] U.S. Energy Information Administration. 2023. *Annual Energy Outlook 2023: Table 3. Energy Prices by Sector and Source*.
[78] Electric Reliability Council of Texas. "Training Courses: Locational Marginal Pricing". Accessed April 24, 2024.

A.2 Ancillary Services

A.2.1 Rationale

The electricity generated by a customer-sited solar resource **reduces the ERCOT load, leading to decreased ancillary service costs.** Solar's impact on ancillary costs primarily encompasses the Regulation Up Service, representing the capacity capable of immediately increasing generation.

The decision to focus solely on the Regulation Up Service is grounded in a solar load-following analysis. This analysis suggests that solar generation in Texas offers a net positive load-following benefit, aligning with hourly forecasted grid demand over a year. Other ancillary services were excluded from the analysis due to their connection to capacity, which is absent in the ERCOT wholesale energy market. However, individual utilities can reduce all ancillary services obligations by reducing their load.

A.2.2 Methodology

Step 1: Establish Historical Avoided Ancillary Service Costs

- To establish the avoided ancillary service costs, historical hourly Day-Ahead ERCOT Market Clearing Ancillary Service Prices were utilized. This analysis focuses solely on the Regulation Up ancillary service. As a first step, the hourly data for Historical Regulation Up Ancillary Service Price was gathered from 2022 to 2023.[79]
- These costs were established on a per MWh of load basis

Step 2: Forecast Avoided Ancillary Service Costs

- The hourly SPPs established in the Avoided Energy Costs section were used to calculate hourly ancillary service prices as a percentage of the system energy price (SPP). This method captures hourly variations in ancillary service prices.
- The average annual Ancillary Service Prices and System Energy Prices from Potomac Economics, an Independent Market Monitor for ERCOT, was determined to establish the average annual ancillary services cost to system energy price ratio.[80]
- For each hour of each year, the hourly ancillary service to system energy price ratio was multiplied by:
    - The annual ancillary service cost to system energy price ratio.
    - The annual avoided energy cost (as developed in Section A.1). This approach accounts for long-term macroeconomic factors, such as natural gas pricing forecasts and the hourly solar generation profile.

[79] Electric Reliability Council of Texas. "DAM Clearing Prices for Capacity". Accessed June 6, 2024.
[80] Potomac Economics. (May 2023). *2022 State of the Market Report for the ERCOT Electricity Markets*.

A.2.3 Inputs, Assumptions, and Notes

Inputs	Sources
Market Clearing Prices for Ancillary Services	ERCOT DAM Clearing Prices
Historical Settlement Point Prices	ERCOT Historical DAM Load Zone and Hub Prices (see section A.1.3)
Annual Average Ancillary and System Energy Costs	2022 State of the Market Report for the ERCOT Electricity Markets
PVWatts Profile	NREL PVWatts - Same inputs as PVWatts profile outlined in Section A.1

Assumptions and Notes

- Selection of Ancillary Services: Five ancillary services exist within the ERCOT wholesale market: Regulation Up, Regulation Down, Responsive Reserve Service, Non-Spin Reserve Service, and ERCOT Contingency Reserve Service. The reserve requirements of ERCOT are based on the single largest generator. Therefore, it is expected that solar will not reduce the overall reserve requirements and may not provide reserve benefits. However, solar can help reduce the need for Regulation Up services due to its load-reducing effect on the regulation services.

A.3 Wholesale Market Price Suppression (DRIPE)

A.3.1 Rationale

The electricity exported by a solar resource reduces the overall energy procured in the wholesale market, thereby decreasing market clearing prices. This Demand Reduction-Induced Price Effect (DRIPE) ultimately translates into cost savings for all market participants.

A.3.2 Methodology

Step 1: Develop Zonal Generation Profiles

- The same approach outlined in Section A.1 was followed.

Step 2: Calculate Gross Energy DRIPE

- Each year's 8760 Gross Energy DRIPE was derived by multiplying hourly avoided energy costs with DRIPE elasticities.[81] This approach accounts for the relationship between electricity prices and demand.
- The diminishing energy DRIPE over time was accounted for by multiplying the Gross Energy DRIPE by one less the resource fade-out factor.[82]

Step 3: Evaluate the First-Year Impact of Solar Installation

- The net first-year impact of a 15-year impact period solar installation was evaluated by calculating the initial installment payment of the net present value stream of the decayed Gross Energy DRIPE, utilizing the public discount rate.
- Steps 2 and 3 were repeated for each year from 2025 through 2050.

A.3.3 Inputs, Assumptions, and Notes

Inputs	Sources
DRIPE Elasticities	AESC Avoided Energy Supply in New England: 2024 Report
DRIPE Decay Factor	AESC Avoided Energy Supply in New England: 2024 Report
PVWatts Profile	NREL PVWatts - Same inputs as PVWatts profile outlined in Section A.1

Assumptions and Notes

- Type of DRIPE: This analysis focuses on the high-level direct price-suppression benefits resulting from reduced energy (Energy DRIPE). The price-suppression benefits associated with reduced capacity, Capacity DRIPE, were not considered due to the absence of capacity in the ERCOT Wholesale Market.

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[81] Synapse Energy Economics, Inc. February 2024. *Avoided Energy Supply Components in New England: 2024 Report*. AESC 2024 Study Group.
[82] *Ibid*.

- Impact Assessment Years: The wholesale market price suppression assessment involves considering the system impacts of a solar asset installed in a given year. Specifically, the system impacts of energy and price reduction were evaluated annually over a certain period following the system's installation. This study assesses impacts over 15 years, assuming effects are negligible after this point.
- Diminishing DRIPE Effects: This study assumes that energy DRIPE diminishes over time as resources respond to price changes and demand elasticity. For example, if energy prices decrease, customers may respond by using more energy, mitigating the price suppression. The elasticity and resource fade-out factors quantify the decay effect.
- Price Elasticity: The price elasticities and decay factors were sourced from the AESC 2024 study. We did not develop Texas-specific price elasticities; however, the average price elasticity assumed in this analysis is -1.3, close to the national average price elasticity of -1. The national long-run price elasticities were developed for the 48 states in the US over the 2003-2015 period. Burke, Paul J., and Ashani Abayasekara. "The Price Elasticity of Electricity Demand in the United States." The Energy Journal 39, no. 2 (March 2018): 123-146. https://www.jstor.org/stable/26534427.

A.4 Hedging/Wholesale Risk Premium

A.4.1 Rationale

The full retail price of electricity typically exceeds the combined wholesale market prices for energy and ancillary services. This discrepancy partly arises because Retail Electric Providers (REPs) face various market risks when setting contract prices before supply delivery periods. Therefore, any reduction in wholesale energy and capacity obligations may lower the REPs' costs associated with mitigating such risks.

Behind-the-meter solar generation acts as a hedge against fuel price costs required to power the marginal resource. Since ERCOT procures energy from various power generators, the fuel price risk in this market is ultimately borne by customers.

A.4.2 Methodology

Step 1: Determine the Risk Premium Factor

- A literature review was conducted using other studies and utility-specific data to determine the most appropriate value for this study.[83]

Step 2: Apply to Avoided Energy Costs

- The risk premium percentage was multiplied by the annual Avoided Energy Costs developed in section A.1 to calculate the avoided wholesale risk premium.

[83] Synapse Energy Economics, Inc. February 2024. *Avoided Energy Supply Components in New England: 2024 Report*. AESC 2024 Study Group.

A.4.3 Inputs, Assumptions, and Notes

Inputs	Sources
Risk Premium Percentage	AESC Avoided Energy Supply in New England: 2024 Report, S&P 500 Market Reports,

Assumptions and Notes

- There are three primary drivers of risk at the wholesale energy market level:[84]
    1. Costs incurred by electricity suppliers to mitigate pricing risks from the uncertainty of final electricity prices due to hourly energy balancing and ancillary services.
    2. Discrepancies between projected and actual energy requirements under supplier and buyer contracts, influenced by fluctuating weather conditions, economic activity, and customer migration.
    3. Risks associated with utility Standard Service Offers (SSO) and customer migration. While the SSO component is irrelevant in the ERCOT market, where Standard Service Offers do not exist, customer migration remains a risk.

A.5 Transmission Capacity

A.5.1 Rationale

ERCOT uses a "postage stamp" rate to cover investments in upgrading and maintaining regional bulk transmission infrastructure.[85] All distribution service providers (DSPs) in ERCOT pay the same rate, based on the total Transmission Cost of Service and their contribution to the ERCOT four-coincident peak (4CP). These costs are passed on to electricity customers assessed annually. Therefore, solar generation that coincides with ERCOT 4CP can avoid or defer some transmission capacity upgrades, leading to avoided transmission capacity costs.

A.5.2 Methodology

Step 1: Establish System-Wide Transmission Charges

- **Establish ERCOT Historical Transmission Charges**: The historical Total ERCOT Postage Stamp Rates were gathered for the years 2020 through 2024.[86]
- **Forecast Transmission Charges**: Annual escalation rates were developed using the historical average transmission charges. These rates were then applied to the current transmission charges (as of 2024) to project transmission costs from 2025 through 2050.

Step 2: Determine Solar's Transmission Capacity Contribution

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[84] *Ibid.*
[85] ERCOT Regional Planning. February 2021. *Consideration of the Appropriate Economic Measure for Evaluating Transmission Project in ERCOT.*
[86] Public Utility Commission of Texas. "Wholesale Transmission Service Charges". Accessed June 6, 2024.

1. **Current Transmission Capacity Contribution:**
    - System-wide historical 4CP (Four Coincident Peaks) events between 2020 and 2023 were gathered.
    - Solar's average coincidence factors during those events was determined to establish its average coincidence factor with ERCOT's transmission system.
    - ERCOT's ELCC (Effective Load Carrying Capability) reports were used to determine solar's average capacity contribution to the overall system.
    - The results from the coincidence factors and the ELCC reports were averaged to estimate the current capacity contribution of solar to the ERCOT transmission system.
2. **Forecast Distributed Solar's Transmission Capacity Contribution:**
    - The ELCC rating for solar was forecasted over the study period using existing studies on solar forecasts in ERCOT and the total utility-scale installed solar from the release of ERCOT's ELCC report (2022) to date (2024).
    - The ELCC forecast was applied to determine the anticipated capacity contribution of solar over the study period.

Step 3: Establish the Transmission Capacity Values for Solar

- The transmission capacity values for solar were then established by multiplying the annual transmission charges by the anticipated capacity contribution from solar over the study period.

A.5.3 Inputs, Assumptions, and Notes

Inputs	Sources
ERCOT Historical 4CP	ERCOT Four Coincident Peak Calculations
ERCOT Historical Postage Stamp Rates	PUCT Net Wholesale Transmission Matrix Charges for ERCOT
ELCC	ERCOT 2022 Effective Load Carrying Capability Study
Solar Forecast: Texas	ERCOT CDR Report

Assumptions and Notes

- **<u>Wholesale Transmission Service Charge Components:</u>** Transmission service charges within the ERCOT territory are determined by various factors and assessed annually by Distribution Service Providers (DSPs). These charges, established through tariffs set by Transmission Service Providers (TSPs), are based on the TSPs' transmission cost of service, including capital costs, infrastructure investments, depreciation, federal income tax, and other associated taxes.[87] Each TSP's transmission service rate is reviewed and set annually, based on the average of the previous year's 4CP demand, coinciding with the ERCOT 4CP.

- **ELCC:** The ELCC factors are instrumental in derating the avoided transmission capacity cost, offering insight into the incremental reliability of each additional megawatt (MW) of distributed solar capacity. The selection of the appropriate ELCC factor for each year hinges upon solar projections specific to Texas, thereby enhancing the accuracy of the analysis and ensuring that the impact of solar generation on the transmission system is appropriately accounted for.

  ERCOT's ELCC report, released in 2022, provides solar ELCC values as a function of cumulative installed solar capacity.[88] As two years have passed since its release, the initial ELCC value in 2024 was determined based on historical utility-scale solar installations in ERCOT for 2023, and the planned installed capacity additions for 2024.

  To determine the historical capacity additions in 2023, the total utility-scale solar capacity in 2022 was subtracted from the total utility-scale solar capacity in 2023, as reported in ERCOT's CDR reports, resulting in an addition of 13,390 MW.[89,90] For the period from 2025 through 2027, ERCOT solar capacity forecasts were used to determine the cumulative installed capacity and, consequently, the ELCC.

  From 2028-onwards, an annual addition of 1,440 MW of solar installations was assumed to develop the ELCC ratings up to 2050. This figure, equal to the planned solar installation in 2027, is likely a conservative assumption.

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[87] Texas Secretary of State. "Texas Administrative Code: Transmission Rates for Export from ERCOT". Accessed June 6, 2024.
[88] Astrapé Consulting. December 2022. *Effective Load Carrying Study: Final Report*. ERCOT.
[89] ERCOT. November 2022. *Report on the Capacity, Demand and Reserves (CDR) in the ERCOT Region, 2023-2032*.
[90] ERCOT. December 2023. *Report on the Capacity, Demand and Reserves (CDR) in the ERCOT Region, 2024-2033*.

A.6 Transmission & Distribution Line Losses

A.6.1 Rationale

The electricity generated by behind-the-meter (BTM) solar resources would reduce the volume of energy that would otherwise be distributed across the transmission and distribution (T&D) network. Inherent within the T&D system are line losses, which decrease proportionally with the reduction in energy flowing through the network. Notably, BTM generation occurs at the customer load level, circumventing transmission line losses entirely. Additionally, for the fraction of solar generation that is self-consumed and not exported to the distribution grid, a corresponding portion of distribution line losses is also eliminated. This dual effect underscores the reduced losses achieved through the integration of BTM solar resources into the electricity system.

A.6.2 Methodology

Step 1: Establish applicable T&D line loss factors.

- Residential-specific transmission and distribution line loss factors were gathered. The T&D line loss factors were established from ERCOT's historical daily loss factor data from 2020 through 2024.[91] In both cases, the marginal losses were assessed, equal to 1.5 times the T&D line losses.
- The formula I^2R mathematically calculates the marginal resistive losses. At any given point on the load duration curve, the marginal resistive losses are twice the average resistive losses. For instance, during off-peak hours when average resistive losses are only 3%, the marginal losses double to 6%. Conversely, during the highest peak hours when average resistive losses are 10%, the marginal losses increase to 20%.[92] However, because part of the overall losses at every hour are (no-load) losses, the marginal losses are not two times the total losses—only two times the resistive losses. Therefore, to account for the low load hours, the marginal losses are assumed to be 1.5 times the average losses.
- To ensure that line losses affect only the energy consumed behind the meter, an appropriate derate factor was calculated. This was done by estimating the proportion of solar energy that is self-consumed behind the meter in a residential home. The calculated derate factor was only applied to the distribution line losses factor.
- The portion of self-consumed solar generation was calculated by comparing the hourly load for an average residential customer in Texas against the hourly solar generation profile of a residential customer using an average solar installation size.[93,94] For any given hour where a residential customer's solar generation exceeds its hourly load, this excess energy is assumed to be exported to the grid (and thus not considered self-consumed).

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[91] Electric Reliability Council of Texas. "Data Aggregation: Key Documents: Historical Loss Factors".
[92] rap-lazar-eeandlinelosses-2011-08-17.pdf (raponline.org)
[93] ResStock. 2021. "Public Datasets: End Use Load Profiles for the U.S. Building Stock". National Renewable Energy Laboratory.
[94] Lawrence Berkely National Laboratory. September 2023. *Tracking the Sun: Pricing and Design Trends for Distributed Photovoltaic Systems in the United States, 2023 Edition*.

Step 2: Apply Line Loss Factors

- Since line losses are directly related to energy consumption, the avoided T&D line losses are multiplied by the avoided energy costs (A.1) and Wholesale Market Price Suppression (A.3).

A.6.3 Inputs, Assumptions, and Notes

Inputs	Sources
Avoided Energy, Wholesale Market Price Suppression	See Sections A.1 & A.3
Avg ERCOT T&D Line Losses	ERCOT Historical Loss Factors
Avg Residential Solar Installation Size	Lawtrence Berkely National Laboratory
Hourly Solar Generation	NREL PVWatts - Same inputs as PVWatts profile outlined in Section A.1
Hourly Residential Load Data	NREL Open Energy Data Initiative

Assumptions and Notes

ERCOT's line loss inputs are based on system-wide averages, which may underestimate the true line loss value provided by BTM solar systems. Additionally, these averages might underrepresent line losses because higher losses often correlate with higher temperatures and ERCOT's high summer loads.

The marginal transmission line losses are calculated as follows:

$$\boldsymbol{Marginal\ Transmission\ LL}\left[\frac{\$}{\boldsymbol{MWh}}\right] = (Avoided\ Energy + Wholesale\ Market\ Price\ Suppression)\left[\frac{\$}{MWh}\right] * (Avg\ ERCOT\ Transmission\ LL)[\%] * \mathbf{1.5}$$

Similarly, for distribution:

$$\boldsymbol{Marginal\ Distribution\ LL}\left[\frac{\$}{\boldsymbol{MWh}}\right] = (Avoided\ Energy + Wholesale\ Market\ Price\ Suppression)\left[\frac{\$}{MWh}\right] * (Avg\ ERCOT\ Distribution\ LL)[\%] * \mathbf{1.5} * Selfconsumed\ generation\ [\%]$$

A.7 Distribution Capacity

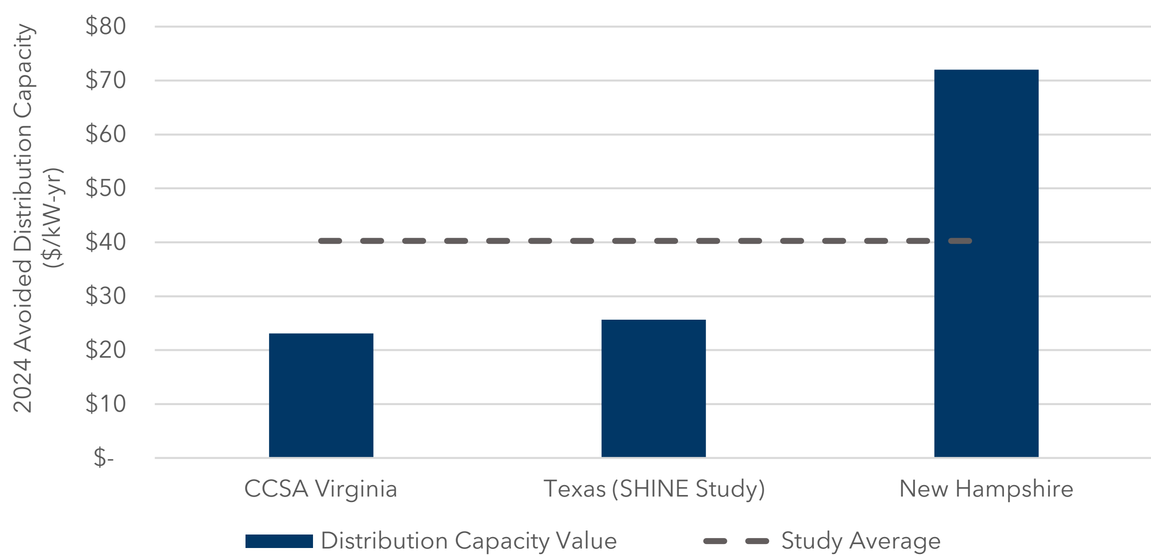
A.7.1 Rationale

The energy produced by net-metered solar can avoid or defer distribution capacity upgrade costs if it reduces load at hours associated with reliability concerns (i.e., during peak hours that would otherwise drive investments in distribution system upgrades). Customers in competitive markets are charged a Distribution Cost Recovery Factor (DCRF) to recover these costs. By leveraging solar energy to defer some of these capacity upgrade expenses, distribution service providers can effectively mitigate some distribution capacity costs.

A.7.2 Methodology

Step 1: Establish System-Wide Proxy

- A meta-analysis of distribution capacity values was conducted, derived from various existing Value of Solar studies. This aimed to estimate annual per unit system-wide avoided distribution costs in $/kW. The analysis averaged values from a Virginia Value of Solar study, a New Hampshire (NH) Value of DER study, and a public model assessing the value of distributed solar projects.[95] [96] [97] Despite being an outlier, the NH value was included due to its comprehensive, location-specific methodology, which provides greater accuracy compared to the state-wide approaches of the other studies, given the highly location-specific nature of avoided distribution capacity costs.[98]



[95] Dunsky Energy + Climate Advisors. November 2023. *Value of Shared Solar in Virginia*.
[96] Dunsky Energy + Climate Advisors. February 2023. *New Hampshire Value of Distributed Energy Resources*.
[97] Rocky Mountain Institute. "SHINE™: DISTRIBUTION SCALE SOLAR". Accessed June 6, 2024.
[98] Guidehouse. July 2020. *New Hampshire Locational Value of Distributed Generation Study*. New Hampshire Public Utilities Commission.

Step 2: Apply to Peak Load Hours

- Since reliability concerns drive distribution system upgrades, the annual $/kW avoided distribution capacity cost was derated by Solar's ELCC.

A.7.3 Inputs, Assumptions, and Notes

Inputs	Sources
Avoided Distribution Cost	Dunsky Energy + Climate Advisors; Dunsky Energy + Climate Advisors; Rocky Mountain Institute
Solar ELCC	ERCOT 2022 Effective Load Carrying Capability Study

Assumptions and Notes

- The effects of solar generation on the distribution system vary depending on the location of the customer-sited PV system. In certain scenarios, PV generation may result in savings by avoiding upgrade costs. However, in other cases, it could necessitate additional capital expenses, particularly if PV is installed on a circuit with low usage, causing reverse energy flow. It can, therefore, be challenging to develop a system-wide applicable avoided value. Individual utilities are better positioned to calculate the value to their systems.

A.8 Air Pollutant Reduction Benefits

A.8.1 Rationale

Electricity generated from solar assets can help reduce marginal pollution and air pollutants from fossil fuel plants. These air pollutants negatively affect air quality, human health, and ecosystem health. Although quantifying these effects can be challenging, they have significant economic and social implications. By reducing the reliance on fossil fuel plants through solar generation, economic benefits can be achieved through the reduction of air pollutants.

A.8.2 Avoided Cost Methodology

Step 1: Determine Marginal Emission Rates

- The non-baseload marginal pollution for Texas' electricity grid were gathered for common air pollutants, including NO_x and SO_2.[99] This represents the base year's level of air pollutant pollution.

Step 2: Calculate the Emission Reduction Benefit of Air Pollutants (2025-2050)

1. **Assessment of Marginal Pollution Reductions:**
    - The reduction in marginal pollution resulting from deploying a 1 kW solar asset was evaluated, considering its capacity to displace energy generated from fossil fuels.
    - The marginal pollution of two air pollutants were assessed: NO_x and SO_2.
2. **Monetary Value of Health Benefits:**
    - The United States Environmental Protection Agency (EPA) COBRA (Co-Benefits Risk Assessment Health Impacts Screening and Mapping Tool) tool was used to quantify the monetary value of health benefits arising from the displacement of natural gas combustion by the 1 kW solar asset.[100]
    - The resulting monetary benefit represents the avoided cost in the base year, 2025.
3. **Solar-Weighted Average Air Pollutant Reduction Benefit:**
    - A yearly solar-weighted average Air Pollutant Reduction Benefit was calculated by multiplying the avoided monetized health impact data with each region's hourly normalized solar generation profile.
    - This series of data was summed to evaluate the total year's solar-weighted Air Pollution Reduction Benefit for 2025.
    - The resulting monetary benefit represents the avoided cost in the base year, 2025.

[99] U.S. Environmental Protection Agency. 2022. "eGRID Data Explorer". Accessed June 6, 2024.
[100] U.S. Environmental Protection Agency. "Co-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA)". Accessed June 6, 2024.

4. **Forecasting the Air Pollution Reduction Benefit (2025 to 2050):**
   - As a proxy, the long-run CO_2-equivalent marginal pollution rates trend for electricity generation in the ERCOT region was used to forecast the benefit.[101]
   - For each year, the marginal pollution rate was multiplied by the corresponding normalized solar generation profile for each hour and summed to determine the annual avoided marginal pollution due to solar generation.
   - The Air Pollution Reduction Benefit for each year was calculated by comparing the avoided marginal pollution relative to the base year's avoided marginal pollution.

A.8.3 Inputs, Assumptions, and Notes

Inputs	Sources
Natural Gas Marginal Pollution	EPA eGRID
Monetary Health Impacts	EPA COBRA
Hourly Solar Generation	NREL PVWatts - Same inputs as PVWatts profile outlined in Section A.1

Assumptions and Notes

- Pollution Intensity: It is assumed the intensity of marginal air pollutant pollution follows the CO_2-equivalent rate of pollution from 2025 to 2050.
- EPA COBRA: The COBRA tool evaluates public health impacts by correlating sector—and state-specific pollution corresponding to changes in health outcomes, such as premature mortality, heart attacks, asthma exacerbation, and lost work days. It then assigns a monetary value to each health impact based on factors like the average cost of emergency room visits for asthma symptoms or individuals' willingness to pay to avoid adverse health effects. This assessment determines the monetized health impacts associated with emission reductions.

[101] National Renewable Energy Laboratory. 2023. "Long-run Marginal Emissions Rates for Electricity – Workbooks for 2023 Cambium Data". Accessed June 6, 2024. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy.

A.9 Greenhouse Gas Pollution Reduction Benefits

A.9.1 Rationale

Electricity produced by a solar asset can mitigate marginal pollution from fossil fuel plants. Greenhouse gas (GHG) pollution and the resulting climate changes negatively impact air quality, human health, agricultural productivity, property damage from climate-related disasters, and ecosystem health. Although quantifying these impacts can be challenging, they have significant economic and social consequences. Reducing electricity generation from fossil fuel plants through solar energy can yield economic benefits via pollution reductions.

A.9.2 Avoided Cost Methodology

Step 1: Determine Avoided Marginal Pollution

- The long-run marginal greenhouse gas pollution for electricity generation in Texas were gathered and measured in CO_2-equivalent terms.[102]
- To establish the avoided marginal pollution from solar generation, the hourly marginal pollution for each year were multiplied by the normalized hourly solar generation profile. This data was then summed to determine the annual avoided marginal pollution from solar generation, expressed in kg CO_2e/MWh.

Step 2: Calculate the Emission Reduction Benefit of GHGs (2025-2050)

- The EPA's Social Cost of Greenhouse Gases (SC-GHG) was used to quantify the monetary benefits of displacing fossil fuel combustion with solar energy. This involved multiplying each year's SC-GHG (including CO_2, CH_4, and N_2O) by the avoided marginal pollution, using a discount rate of 2.5%.

A.9.3 Inputs, Assumptions, and Notes

Inputs	Sources
Natural Gas Marginal Pollution	NREL Cambium
Social Cost of Greenhouse Gases	EPA Social Cost of Greenhouse Gases
Hourly Solar Generation	NREL PVWatts - Same inputs as PVWatts profile outlined in Section A.1

Assumptions and Notes

- EPA Social Cost of Greenhouse Gases: In November 2023, the EPA released an updated SC-GHG report, reflecting recent scientific advancements regarding the detrimental impacts of greenhouse gas pollution on both the climate and economy. This report quantifies the public benefit of reducing GHG pollution by one metric ton, accounting for

[102] National Renewable Energy Laboratory. 2023. "Long-run Marginal Emissions Rates for Electricity – Workbooks for 2023 Cambium Data". Accessed June 6, 2024. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy.

changes in agricultural productivity, human health, damage from increased floods and natural disasters, and other relevant factors.

A.10 Potential Sources of Uncertainty

Components	Key Factors
Avoided Energy Costs	• **Natural Gas Prices:** Combined cycle gas turbines (CCGT) and dual fuel gas turbines typically serve as the marginal generating resources, and thus changes in natural gas prices have a significant impact on marginal energy prices. Natural gas prices usually respond to supply and demand dynamics. An increase in supply can lower prices, as has been recently observed across North America, leading to reduced avoided energy costs. Conversely, insufficient supply can cause natural gas prices and energy costs to rise.
Risk premium	• **The risk-free rate** (typically dictated by public markets) used to price hedging products and contracts. • Implied **volatility in commodity prices.**
T&D Line Losses	• Changes in average and marginal system line losses (load variability, transformer losses, etc.) • Value of avoided energy costs (directly proportional to T&D line losses). • The percentage of self-consumed solar at the customer load level.
Avoided T&D Capacity costs	• **Coincidence with solar generation:** Peak load demand projections are crucial for energy system planning and grid management. However, relying solely on the headline system peak load demand metric to decide future T&D capacity upgrades can lead to misconceptions. While system-wide demand may peak during non-solar hours, localized transmission and distribution capacity constraints during solar coincident generation could prevent costly upgrades in specific regions. Ultimately, the alignment between BTM solar generation and demand pockets is contingent upon customer segmentation, end-use profiles, and the dynamic evolution of load-shifting strategies (demand response, storage) within the electricity system. • **T&D infrastructure needs:** T&D benefits from solar ultimately depend on the underlying need for T&D investments. With increasing electrification and load growth, more localized system pain points will likely emerge, and DERs can serve as a cost-effective non-wire solution that can avoid or defer investments in traditional poles and wires. • **T&D infrastructure project/capital cost projections:** T&D capacity capital project costs and timelines can change due to material & labor shortages, regulatory compliance, and risk.

Appendix B: Data Tables

B.1 ERCOT Value of Solar

Table B-1. ERCOT Value of solar, 2024 $/kWh.

Year	Energy	Ancillary	DRIPE	Risk Premium	Trans. Capacity	T&D Line Losses	Distrib. Capacity	Air Pollutant Reduction	GHG Pollution Reduction	Total Grid Benefits	Total Grid + Public Benefits
2025	$0.09	$0.00	$0.01	$0.01	$0.02	$0.01	$0.01	$0.02	$0.10	**$0.14**	**$0.26**
2026	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.10	**$0.13**	**$0.25**
2027	$0.08	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.09	**$0.13**	**$0.24**
2028	$0.08	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.09	**$0.13**	**$0.22**
2029	$0.08	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.08	**$0.12**	**$0.22**
2030	$0.08	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.07	**$0.13**	**$0.21**
2031	$0.08	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.07	**$0.13**	**$0.20**
2032	$0.08	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.06	**$0.13**	**$0.19**
2033	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.05	**$0.13**	**$0.18**
2034	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.04	**$0.13**	**$0.17**
2035	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.02	**$0.13**	**$0.16**
2036	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.02	**$0.13**	**$0.16**
2037	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.02	**$0.14**	**$0.16**
2038	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.02	**$0.14**	**$0.16**
2039	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.02	**$0.14**	**$0.16**
2040	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2041	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2042	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2043	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2044	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2045	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2046	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.17**

Year	Energy	Ancillary	DRIPE	Risk Premium	Trans. Capacity	T&D Line Losses	Distrib. Capacity	Air Pollutant Reduction	GHG Pollution Reduction	Total Grid Benefits	Total Grid + Public Benefits
2047	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.17**
2048	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.03	**$0.14**	**$0.17**
2049	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.03	**$0.14**	**$0.17**
2050	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.03	**$0.14**	**$0.18**
Avg	**$0.09**	**$0.00**	**$0.01**	**$0.01**	**$0.01**	**$0.01**	**$0.01**	**$0.01**	**$0.04**	**$0.14**	**$0.18**

Table B-2. ERCOT North Load Zone Value of solar, 2024 $/kWh

Year	Energy	Ancillary	DRIPE	Risk Premium	Trans. Capacity	T&D Line Losses	Distrib. Capacity	Air Pollutant Reduction	GHG Pollution Reduction	Total Grid Benefits	Total Grid + Public Benefits
2025	$0.09	$0.00	$0.01	$0.01	$0.02	$0.01	$0.01	$0.02	$0.10	**$0.14**	**$0.26**
2026	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.10	**$0.13**	**$0.25**
2027	$0.08	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.09	**$0.13**	**$0.23**
2028	$0.08	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.09	**$0.12**	**$0.22**
2029	$0.08	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.08	**$0.12**	**$0.21**
2030	$0.08	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.07	**$0.12**	**$0.21**
2031	$0.08	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.07	**$0.12**	**$0.20**
2032	$0.08	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.06	**$0.13**	**$0.19**
2033	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.05	**$0.13**	**$0.18**
2034	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.04	**$0.13**	**$0.17**
2035	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.02	**$0.13**	**$0.16**
2036	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.02	**$0.13**	**$0.16**
2037	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.02	**$0.13**	**$0.16**
2038	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.02	**$0.13**	**$0.16**
2039	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.13**	**$0.16**
2040	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2041	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2042	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**

Year	Energy	Ancillary	DRIPE	Risk Premium	Trans. Capacity	T&D Line Losses	Distrib. Capacity	Air Pollutant Reduction	GHG Pollution Reduction	Total Grid Benefits	Total Grid + Public Benefits
2043	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2044	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2045	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2046	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2047	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.17**
2048	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.03	**$0.14**	**$0.17**
2049	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.03	**$0.14**	**$0.17**
2050	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.03	**$0.14**	**$0.17**
Avg	**$0.09**	**$0.00**	**$0.01**	**$0.01**	**$0.01**	**$0.01**	**$0.01**	**$0.01**	**$0.04**	**$0.13**	**$0.18**

Table B-3. ERCOT Houston Load Zone Value of solar , 2024 $/kWh

Year	Energy	Ancillary	DRIPE	Risk Premium	Trans. Capacity	T&D Line Losses	Distrib. Capacity	Air Pollutant Reduction	GHG Pollution Reduction	Total Grid Benefits	Total Grid + Public Benefits
2025	$0.09	$0.00	$0.01	$0.01	$0.02	$0.01	$0.01	$0.02	$0.10	**$0.14**	**$0.26**
2026	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.10	**$0.14**	**$0.25**
2027	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.09	**$0.13**	**$0.24**
2028	$0.08	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.09	**$0.13**	**$0.23**
2029	$0.08	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.08	**$0.13**	**$0.22**
2030	$0.08	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.07	**$0.13**	**$0.21**
2031	$0.08	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.07	**$0.13**	**$0.20**
2032	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.06	**$0.13**	**$0.19**
2033	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.05	**$0.13**	**$0.18**
2034	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.04	**$0.13**	**$0.17**
2035	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.02	**$0.14**	**$0.16**
2036	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.02	**$0.14**	**$0.16**
2037	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.02	**$0.14**	**$0.16**
2038	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.02	**$0.14**	**$0.16**

Year	Energy	Ancillary	DRIPE	Risk Premium	Trans. Capacity	T&D Line Losses	Distrib. Capacity	Air Pollutant Reduction	GHG Pollution Reduction	Total Grid Benefits	Total Grid + Public Benefits
2039	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.02	**$0.14**	**$0.16**
2040	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.02	**$0.14**	**$0.16**
2041	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2042	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2043	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2044	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2045	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.17**
2046	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.17**
2047	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.17**
2048	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.03	**$0.14**	**$0.17**
2049	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.03	**$0.14**	**$0.17**
2050	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.03	**$0.15**	**$0.18**
Avg	**$0.09**	**$0.00**	**$0.01**	**$0.01**	**$0.01**	**$0.01**	**$0.01**	**$0.01**	**$0.04**	**$0.14**	**$0.19**

Table B-4. ERCOT South Load Zone Value of solar, 2024 $/kWh

Year	Energy	Ancillary	DRIPE	Risk Premium	Trans. Capacity	T&D Line Losses	Distrib. Capacity	Air Pollutant Reduction	GHG Pollution Reduction	Total Grid Benefits	Total Grid + Public Benefits
2025	$0.09	$0.00	$0.01	$0.01	$0.02	$0.01	$0.01	$0.02	$0.10	**$0.14**	**$0.26**
2026	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.10	**$0.13**	**$0.25**
2027	$0.08	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.09	**$0.13**	**$0.24**
2028	$0.08	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.09	**$0.12**	**$0.22**
2029	$0.08	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.08	**$0.12**	**$0.22**
2030	$0.08	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.07	**$0.12**	**$0.21**
2031	$0.08	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.07	**$0.13**	**$0.20**
2032	$0.08	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.06	**$0.13**	**$0.19**
2033	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.05	**$0.13**	**$0.18**
2034	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.04	**$0.13**	**$0.17**

Year	Energy	Ancillary	DRIPE	Risk Premium	Trans. Capacity	T&D Line Losses	Distrib. Capacity	Air Pollutant Reduction	GHG Pollution Reduction	Total Grid Benefits	Total Grid + Public Benefits
2035	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.02	**$0.13**	**$0.16**
2036	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.02	**$0.13**	**$0.16**
2037	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.02	**$0.13**	**$0.16**
2038	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.02	**$0.14**	**$0.16**
2039	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.02	**$0.14**	**$0.16**
2040	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2041	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2042	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2043	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2044	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2045	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2046	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.17**
2047	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.17**
2048	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.03	**$0.14**	**$0.17**
2049	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.03	**$0.14**	**$0.17**
2050	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.03	**$0.14**	**$0.18**
Avg	**$0.09**	**$0.00**	**$0.01**	**$0.01**	**$0.01**	**$0.01**	**$0.01**	**$0.01**	**$0.04**	**$0.14**	**$0.18**

Table B-5. ERCOT West Load Zone Value of solar, 2024 $/kWh

Year	Energy	Ancillary	DRIPE	Risk Premium	Trans. Capacity	T&D Line Losses	Distrib. Capacity	Air Pollutant Reduction	GHG Pollution Reduction	Total Grid Benefits	Total Grid + Public Benefits
2025	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.02	$0.10	**$0.15**	**$0.27**
2026	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.10	**$0.14**	**$0.25**
2027	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.09	**$0.13**	**$0.24**
2028	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.09	**$0.13**	**$0.23**
2029	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.08	**$0.13**	**$0.22**

Year	Energy	Ancillary	DRIPE	Risk Premium	Trans. Capacity	T&D Line Losses	Distrib. Capacity	Air Pollutant Reduction	GHG Pollution Reduction	Total Grid Benefits	Total Grid + Public Benefits
2030	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.07	**$0.13**	**$0.21**
2031	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.07	**$0.13**	**$0.20**
2032	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.06	**$0.13**	**$0.19**
2033	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.05	**$0.13**	**$0.19**
2034	$0.09	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.04	**$0.14**	**$0.18**
2035	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2036	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2037	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2038	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2039	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2040	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2041	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.16**
2042	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.17**
2043	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.17**
2044	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.14**	**$0.17**
2045	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.15**	**$0.17**
2046	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.15**	**$0.17**
2047	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.02	**$0.15**	**$0.17**
2048	$0.10	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.03	**$0.15**	**$0.18**
2049	$0.11	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.03	**$0.15**	**$0.18**
2050	$0.11	$0.00	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.03	**$0.15**	**$0.18**
Avg	**$0.10**	**$0.00**	**$0.01**	**$0.01**	**$0.01**	**$0.01**	**$0.00**	**$0.01**	**$0.04**	**$0.14**	**$0.19**

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