Valuing and Compensating Distributed Energy Resources in ERCOT

PRESENTED TO

Texas Clean Energy Coalition

PRESENTED BY

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THE Brattle GROUP

Table of Contents

I. Introduction

II. Growth of DER in ERCOT

III. Evaluating the Economics of DER in ERCOT

IV. Compensation for DER in ERCOT

V. Increasing Visibility for DER – Nodal Pricing

VI. DER in ERCOT – Issues for Further Study

VII. Appendix

I. Introduction

The purpose of this study

Distributed Energy Resources (DER) have been expanding rapidly in the Electric Reliability Council of Texas (ERCOT) electric grid. They include:

- Rooftop and community-scale solar PV.
- Distributed battery storage.
- Natural gas-powered microgrids.
- Energy efficiency and demand response.

While DER still accounts for a small portion of ERCOT capacity, DER has become a significant contributor to the Texas power supply.

Brattle was engaged by the Texas Clean Energy Coalition (TCEC) to conduct a study to:

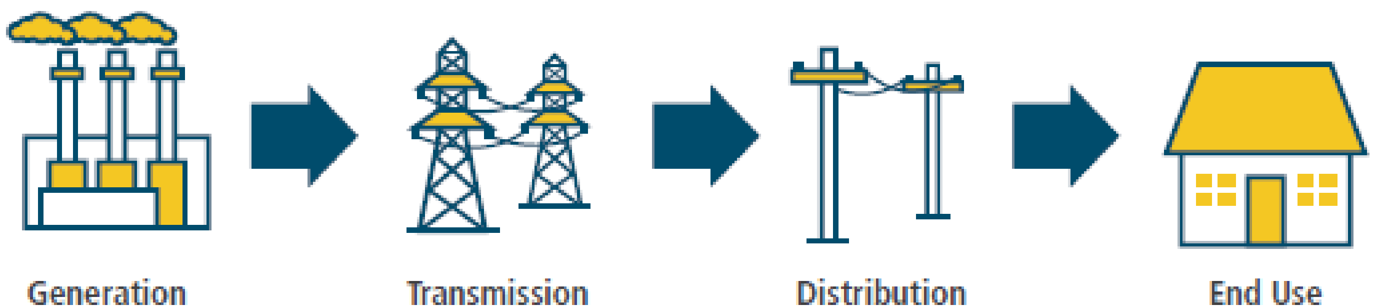
- Examine the potential role of DER in ERCOT.
- Evaluate the economics of DER.
- Explore possible DER policies based on the study's findings.

This study provides the foundation for further stakeholder engagement around market dynamics and policy choices that can accelerate the growth of DER, and how DER can impact resilience during cyberattacks or natural disasters like hurricanes and winter storms, grid reliability and consumer choice for Texans.

The legacy power system

Historically, the flow of power has been in one direction from large generators to customers over high voltage transmission lines and then onto lower voltage distribution lines. The generation and transmission portions of the system are designed to generate and deliver the needed power to customers on the lower voltage distribution subsystem while following the time-varying pattern of aggregate consumer demand.

Figure 1-10. Traditional One-Way Flow Electricity Supply Chain[75]

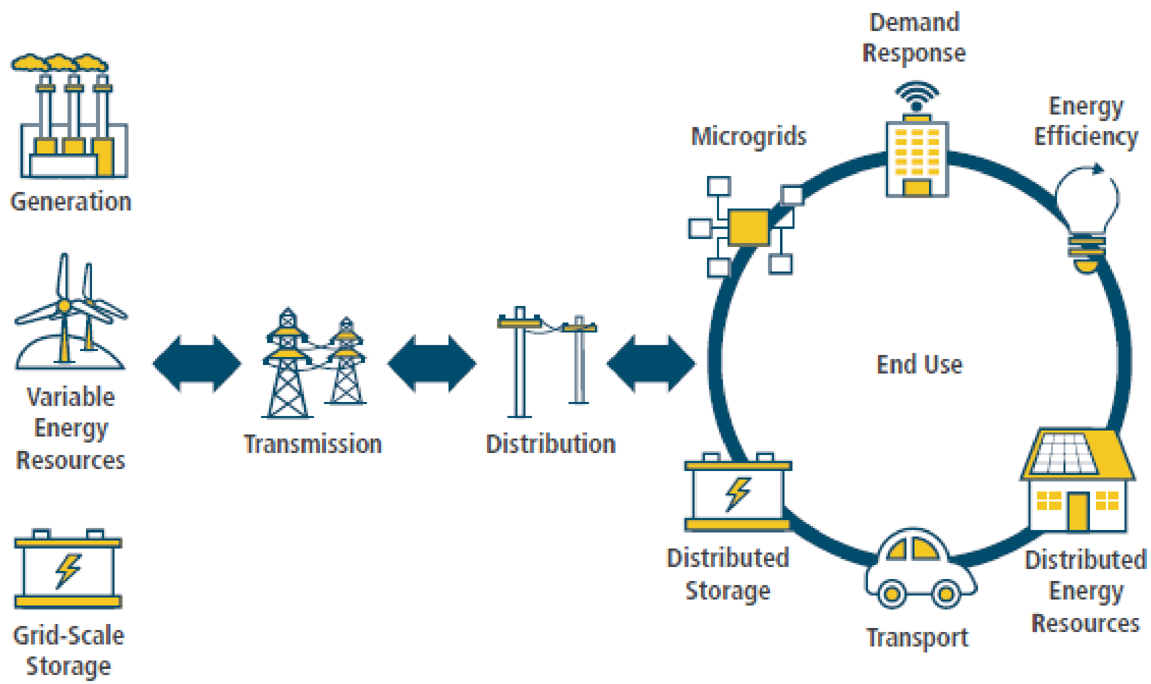


The power grid was traditionally designed to move electricity from large generators to end users. Arrows represent power flows.

Source: DOE QER January 2017

The emerging power system

Figure 1-11. Emerging 21st-Century Electricity Two-Way Flow Supply Chain[76]



The emerging 21st-century power grid will incorporate responsive resources, storage, microgrids, and other technologies that enable increased flexibility, higher system efficiency, reduced energy consumption, and increased consumer options and value. Arrows represent power flows. Figure 1-11 also depicts key factors that are disrupting traditional modes of grid management and operations.

Today, consumers are installing solar PV, battery storage and microgrids as technology costs decline, and consumers act on growing concerns for resilience and environmental impacts.

Some consumers sell their excess DER power back to the grid.

In addition, many consumers use energy efficiency (EE) and demand response (DR) to manage their energy use.

Source: DOE QER January 2017

The disconnect between DER value and compensation

The way customers are charged for electric service is sometimes inconsistent with the the emerging power system.

- Excess DER generation (on-site power generation that exceeds customer demand) is at times sent to the grid without compensation.
- Potential savings in transmission and generation upgrades are indirectly compensated but in a way that sometimes is inconsistent with the value provided by the DER.

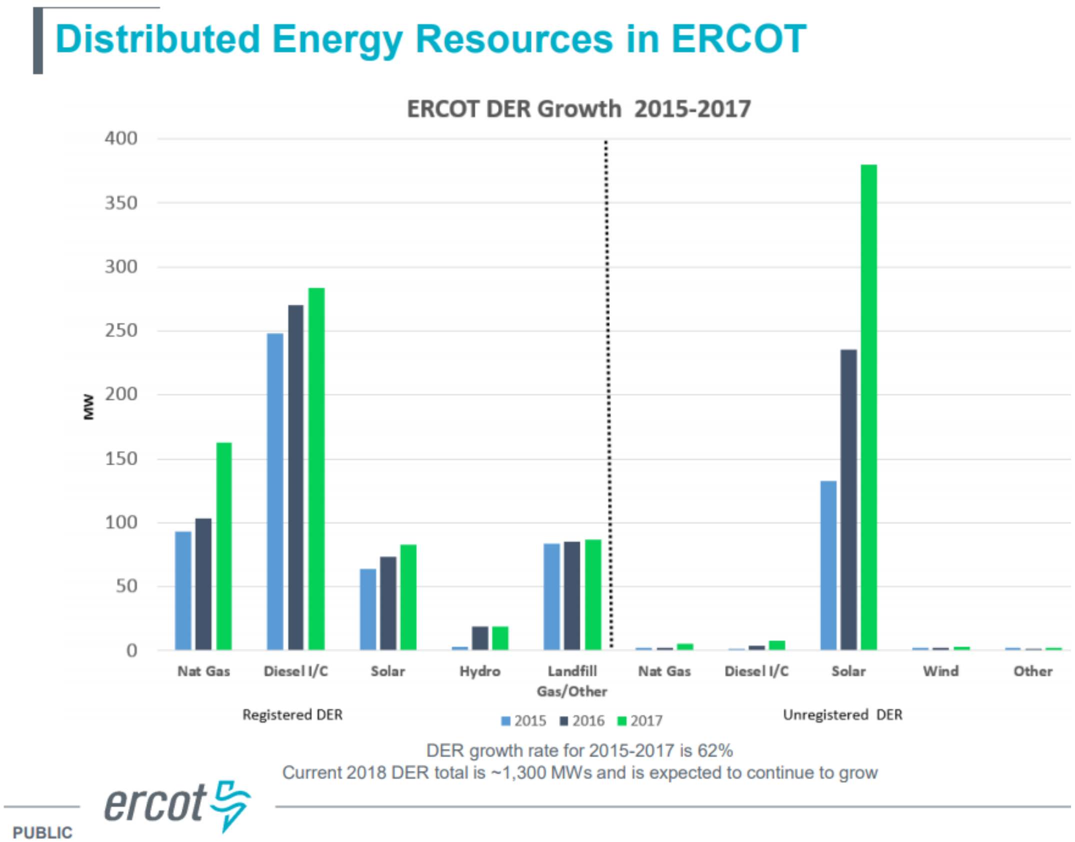
The cost of providing energy to customers varies significantly during different seasons and times of day. Systems with large renewable resource bases have very large swings in hourly energy prices that most customers do not see.

- The higher-than-system-average value of energy from solar power during hot summer days is not reflected in rates that customers pay.
- Similarly, the value of reducing demand during periods of scarcity may not be accurately rewarded.

The study will examine the growth of DER in ERCOT, the economics of DER and issues concerning the disconnect between DER value and compensation.

II. Growth of DER in ERCOT

DER capacity has been increasing in ERCOT



Source: ERCOT Emerging Grid Issues Briefing, November 18, 2018.

* Note: ERCOT Distributed Generation at http://www.ercot.com/services/rq/re/dgresource.

DER in ERCOT grew 62% between 2015 and 2017. By the end of 2018, there were about 1,300 MW of DER in ERCOT. Continued growth is expected.

Solar development is accelerating with the continued decline in solar costs and the desire of some customers to generate their own power, although the phaseout of the federal investment tax credit could dampen solar development.

DER between 1 MW and 10 MW that exports power to the ERCOT grid is required to be registered with ERCOT, unless it is solely for backup power and never exports to the grid.*

DER under 1 MW growth Q3-Q4 2018

A snapshot of small DER growth between Q3 and Q4 of 2018 shows most activity in distributed solar power.

2018 Q3 Unregistered Distributed Generation Report

Load Zone	2018 Q4 Aggregate MW by Primary Fuel Type				
	SOLAR	WIND	OTHER RENEWABLE	OTHER NON-RENEWABLE	TOTAL
LZ_AEN	18.58	-	-	-	18.58
LZ_CPS	22.99	-	0.23	-	23.22
LZ_HOUSTON	14.49	0.36	0.11	4.34	19.31
LZ_LCRA	12.71	-	-	-	12.71
LZ_NORTH	115.39	2.59	-	0.71	118.68
LZ_RAYBN	1.90	-	-	-	1.90
LZ_SOUTH	30.89	0.87	-	-	31.76
LZ_WEST	10.21	0.77	-	0.34	11.33
TOTAL	227.17	4.59	0.34	5.39	237.48

Load Zone	2018 Q3 → Q4 Change in Aggregate MW by Primary Fuel Type				
	SOLAR	WIND	OTHER RENEWABLE	OTHER NON-RENEWABLE	TOTAL
LZ_AEN	+0.81	-	-	-	+0.81
LZ_CPS	+2.81	-	-	-	+2.81
LZ_HOUSTON	+4.00	-	-	-	+4.00
LZ_LCRA	+0.25	-	-	-	+0.25
LZ_NORTH	+8.95	+0.01	-	-	+8.96
LZ_RAYBN	-	-	-	-	+0.00
LZ_SOUTH	+8.89	+0.01	-	-	+8.90
LZ_WEST	+0.65	-0.01	-	-	+0.64
TOTAL	+26.36	+0.01	-	-	+26.36

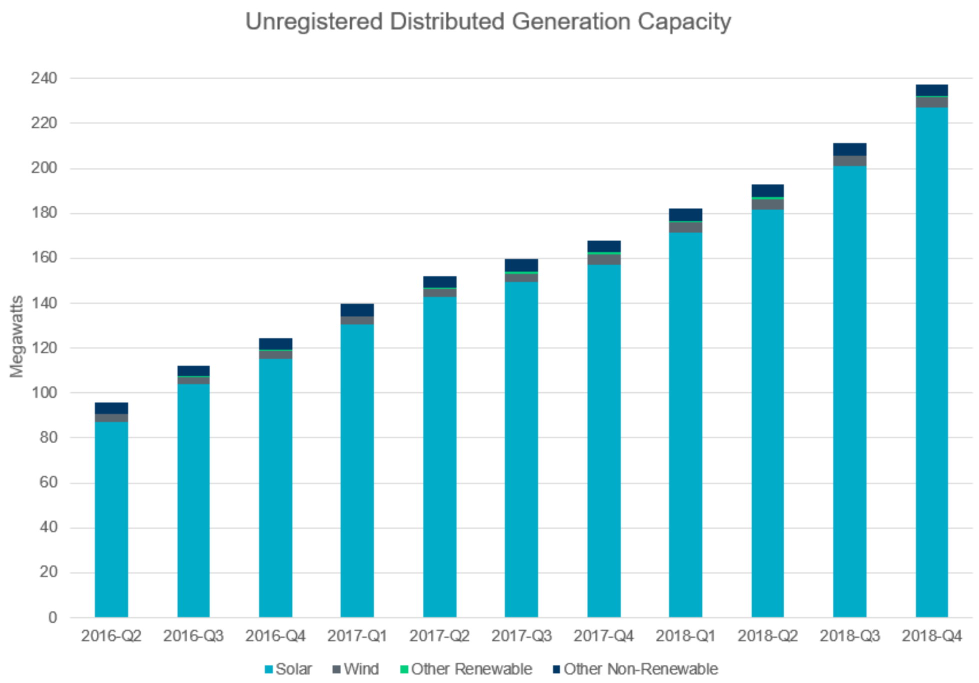
PUBLIC ercot 2

Source: ERCOT Unregistered Distributed Generation Report: 2018.Q4 Update

DER under 1 MW more than doubled 2016-2018

Many rooftop solar installations and some natural gas-powered microgrids are less than 1 MW. ERCOT publishes a quarterly report of unregistered DER.

Unregistered DG Growth: 2016-Q2* to 2018-Q4



*** 2016-Q2 was the first report published after implementation of report changes per NPRR794/COPMGR044**

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Source: ERCOT Unregistered Distributed Generation Report: 2018.Q4 Update

III. Evaluating the Economics of DER in ERCOT

Many potential system values are suggested for DER

Wholesale.

- Avoided energy.
- Avoided generation capacity and O&M.
- Fuel hedge.

Transmission.

- Avoided/deferred transmission investment.
- However, there is also the possibility of increased transmission needs should DER result in retirements that require transmission investment.

Distribution.

- Avoided/deferred distribution investment.
- Feeder voltage control.

Avoided losses (transmission and distribution).

Ancillary services.

Market price reduction.

Externalities.

- Environmental.
- Resilience.
- Jobs.

Different DER technologies provide different benefits

Various forms of DER make different contributions to the grid.

- Some DER provides on-demand power, such as micro-turbines and storage, while others such as solar and wind provide power that varies with the time of day and weather conditions.
- Battery storage has technical limits in terms of its charging and discharging capacity, and energy storage capability.
- Distributed solar power tends to have better coincidence with late-afternoon peak demand than wind power, but the correlation is not perfect.
- Wind and solar power, EE and DR have zero carbon emissions, while micro-turbines or other distributed generators powered by natural gas may contribute to carbon emissions, but at a much lower rate than coal-fired power plants.

Value of DER studies vary in valuation, methodology

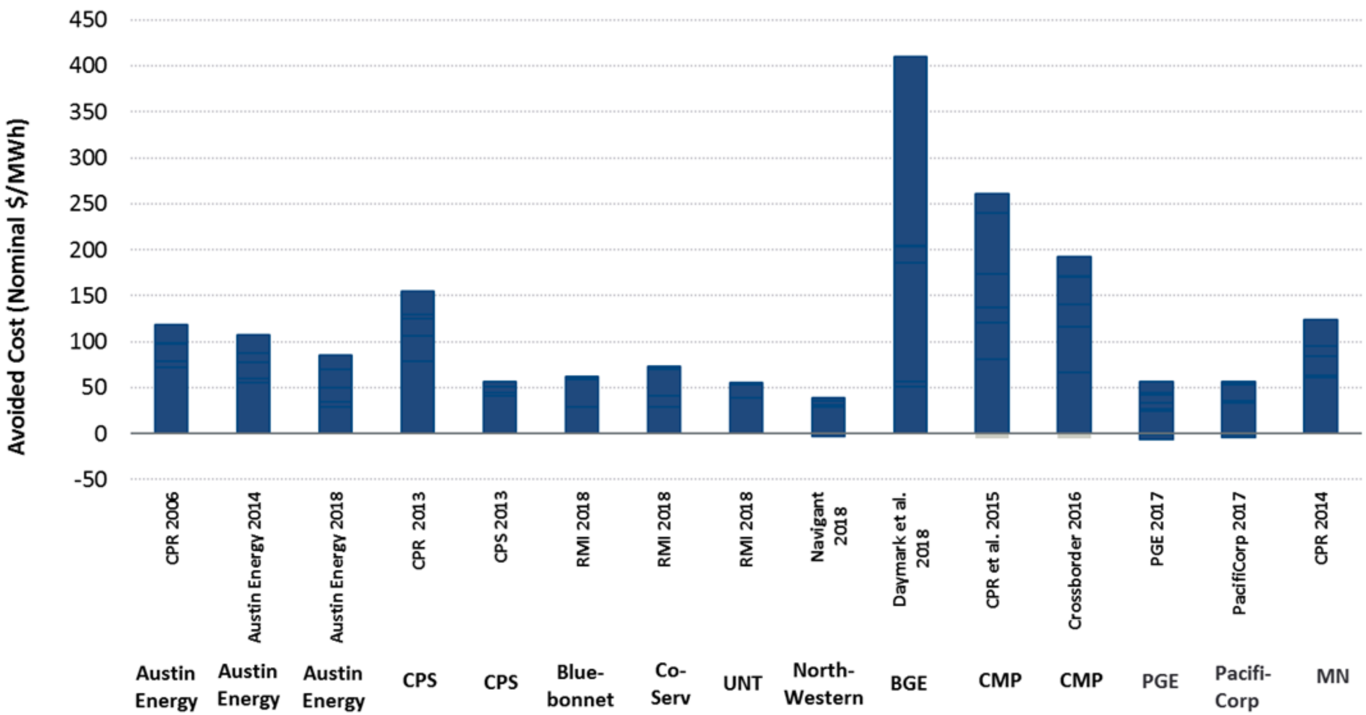
The prior Value of DER (VoD) research that has been done on rooftop solar power, seeking to understand the value streams associated with DER and the methodologies that have been used to calculate those values, have reached only limited consensus about the set of values that DER provides.

- There is universal agreement that energy and, for some regions, capacity should be included. Moreover, these factors are usually the most significant.
- Transmission and distribution values are usually recognized, but the valuation approaches differ with some studies based on embedded cost and other studies based on cost deferral. In addition, some studies recognize the locational value differences.
- There is agreement that some DER has environmental benefits, but determining an appropriate value can be difficult. For example, should a DER receive a monetary reward if other technologies with the same positive environmental attributes are not rewarded?
- Other factors such as “macroeconomic benefits,” the economic activity induced by spending on DER, and wholesale price reduction are not unique attributes of DER and are controversial.

Value of Solar estimates vary dramatically

The estimated Value of Solar (VoS) varies from $30/MWh to $420/MWh, depending on what is being valued, the region, and the methodology in the study.

Summary of Value of Solar in Reviewed Studies

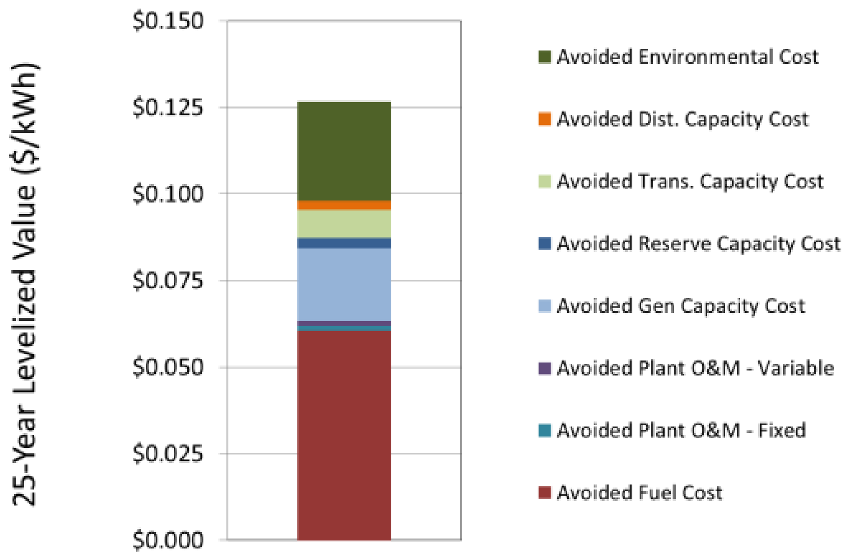


Value of Solar in Minnesota

Minnesota has adopted a VoS that a Minnesota utility can opt to use as an alternative to net metering, but none have elected to use it. It is however being used for community solar.

- The tariff will be updated annually to reflect changes in the electric system such as fuel prices and utility hourly load profiles.
- Consumers who have entered into the tariff in previous years will not be affected by the adjusted tariff except for inflation, hence they are locked into an inflation-adjusted rate for the 25-year term of the VoS tariff.

An example of Value of Solar Tariff Evaluated in the Minnesota Study



Source: Clean Power Research, Minnesota Value of Solar: Methodology, April, 9, 2014 https://www.cleanpower.com/wp-content/uploads/MN-VOS-Methodology-2014-01-30-FINAL.pdf

Value of Solar in Oregon

Pacificorp (Oregon Public Service Commission UM 1910) and Portland General (Oregon Public Service Commission UM 1912) both have ongoing proceedings intended to establish a VoS and VoS methodology. The tables below summarize the initial VoS calculated by the two companies.

Value of Solar in Pacific Corp (Nominal Levelized Value in $/MWh)

Element	Value
Avoided energy cost	33.63
Avoided generation capacity cost	17.96
Avoided transmission and distribution capacity	0.08
Avoided line losses	2.14
Administration	-2.88
Integration	-0.82
Market price response	0.00
Avoided hedge value	1.68
Avoided environmental compliance	0.22
Avoided RPS compliance	0.00
Grid services	0.00
Total	**52.00**

Value of Solar in Portland General (Real Levelized value in 2017 $/MWh)

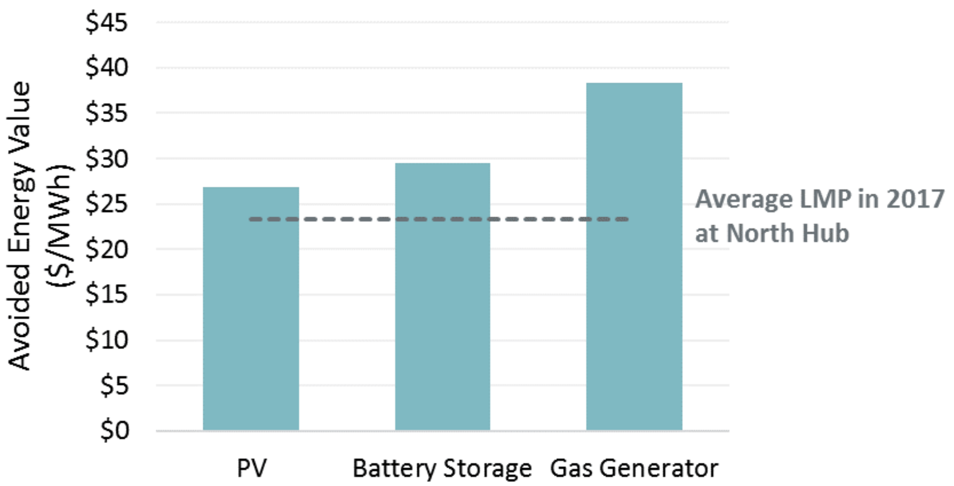
Element	Value
Energy	24.98
Generation Capacity	7.30
T&D Capacity	8.08
Line Loss	1.48
Administration	-5.58
Market Price Response	1.81
Integration	-0.83
Hedge Value	1.25
Environmental Compliance	11.41
RPS Compliance	0.00
Grid Services	0.00
Total	**49.88**

Energy Value of DER in ERCOT

DER can have different values depending on the technology.

- The average avoided energy value for solar PV is higher than the average wholesale energy price because solar power is available during late-afternoon peak hours when prices are relatively high.
- Storage and natural gas generators tend to have higher energy values than solar PV because they can dispatch during high-priced peak hours.

Indicative Energy Values of DER in 2017



Notes: Energy values are calculated based on 2017 hourly day-ahead energy prices for the North hub. Hourly solar profile is based on a residential load profile in Dallas Forth Worth. Battery is assumed to have 2 hours charging duration and 2 hours discharging duration with an efficiency of 80%. Battery is dispatched based on a dispatch rule that charges it at the two hours with the lowest prices during a day and discharges it at the two hours with the highest prices.

ERCOT's 2016 forecast shows potential benefits of DER

The 2016 ERCOT Long-Term System Assessment (LTSA) modeled a few scenarios for long term trends, including a scenario with high DG/EE penetration,* under which:

- Peak demand growth declined by 3% between 2017 and 2031, compared with an increase of 10% in the Current Trends case.
- 8.1 GW more economic retirements and 3.1 GW fewer central station additions (all solar) in 2031 than the Current Trends case.

The LTSA reports reduction in reliability project needs in 2031 compared with the Current Trends case (see the next two slides).

Caveat: The LTSA transmission modeling is at a fairly high level. While the changes in 2031 indicate that DG/EE could have a significant impact on long-term economics, those impacts would require further study of all of the changes across scenarios that could occur over the 15 year period.

* Note: The 2018 LTSA did not report comparable data.

ERCOT North/North Central reliability projects

The 2016 LTSA reports reduction in reliability project needs in 2031 compared with the Current Trends case. The figures below show reliability projects in the current trends (left) and high EE/DG scenarios. With high EE/DG, the pattern of upgrades is slightly different and it appears that fewer are required.

Reliability Projects in North/North Central in Current Trends

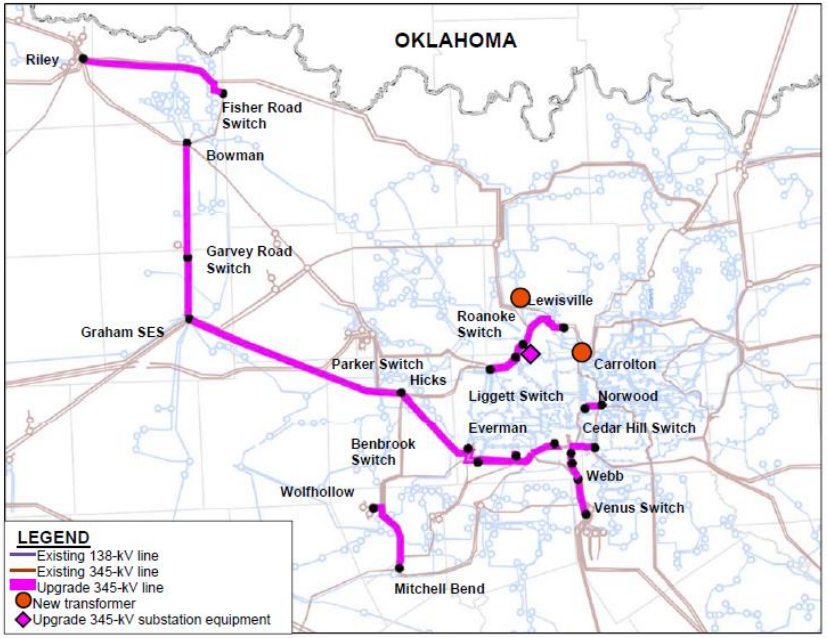


Figure D.7: North/North Central Reliability Projects Identified in the 2016 LTSA Current Trends Scenario

Reliability Projects in North/North Central in High EE/DG

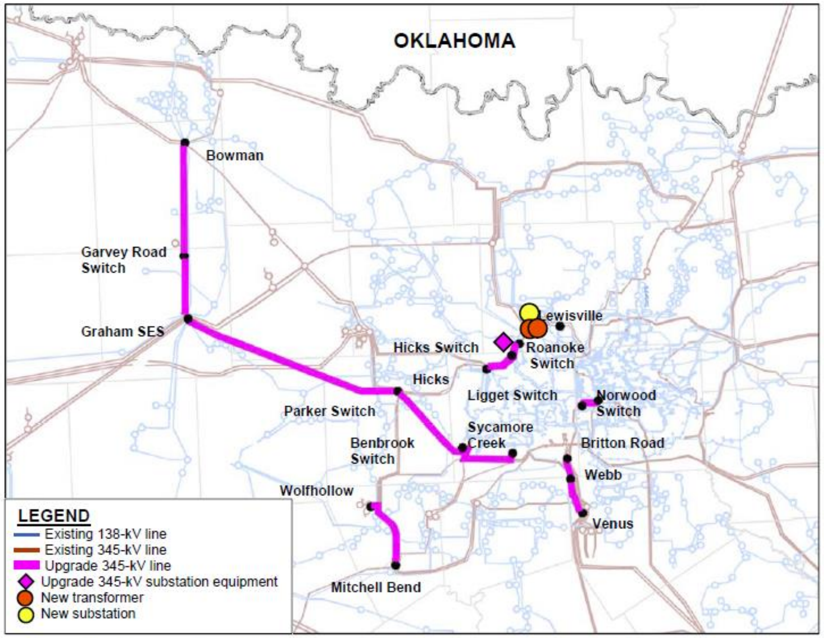


Figure D.9: North/North Central Reliability Projects Identified in the 2016 LTSA High Energy Efficiency and Distributed Generation Scenario

Source: ERCOT 2016 LTSA

ERCOT South/South Central reliability projects

The figures below from the 2016 LTSA show reliability projects in the current trends (left) and high EE/DG scenarios. With high EE/DG, the pattern of upgrades is quite different, deferring or avoiding a 370-mile single circuit 345 kV path through South Texas from Bexar County, west to Del Rio and south to Webb County costing an estimated $500 million.*

Reliability Projects in South/South Central under Current Trends

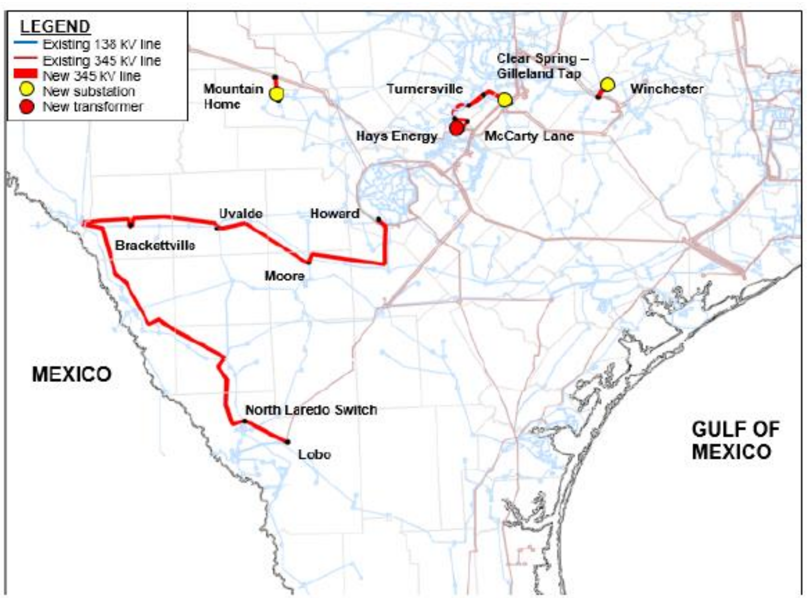


Figure D.4: Current Trends 2031-South and South Central Region Upgrades

Reliability Projects in South/South Central under High EE/DG

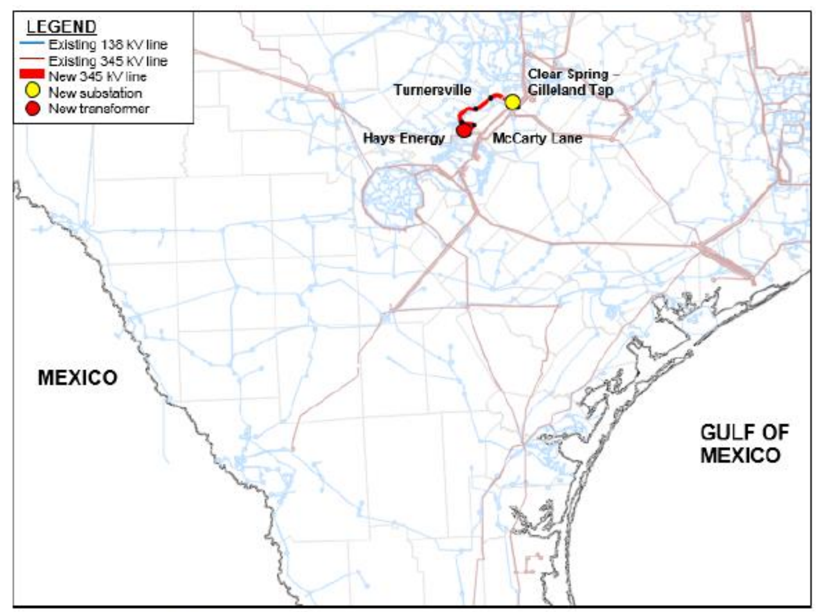


Figure D.6: High EE/DG 2031-South and South Central Region Upgrades

Source: ERCOT 2016 LTSA.
*Note: A single circuit 345 kV line costs $1,343,800 per mile based on the Black & Veatch report “Capital Costs for Transmission and Substations,” February 2014

IV. Compensation for DER in ERCOT

Compensation for Small DER in ERCOT

Some DER in ERCOT is compensated for all the energy produced, but this is not the case for small DER:

- For small DER (<1 MW), energy export to the grid is not compensated except by a few municipalities (Austin, San Antonio, and City of Brenham), and by programs available from a few retail providers (MP2 Energy and Green Mountain).

Since future DER growth in ERCOT is likely to include many of these small, non-registered customer-sited solar PV and battery installations, further stakeholder engagement is needed to explore ways to fully and appropriately compensate them for excess energy produced, thus incentivizing more development of DER.

- While these generators save their hosts money and their excess generation is valuable to the system, those values may not be fully compensated.
- This dampens the financial incentive to invest in these technologies.

However, it is important that any compensation plan should recognize the value of DER to the system and avoid cost shifting so that DER can contribute to the ERCOT grid.

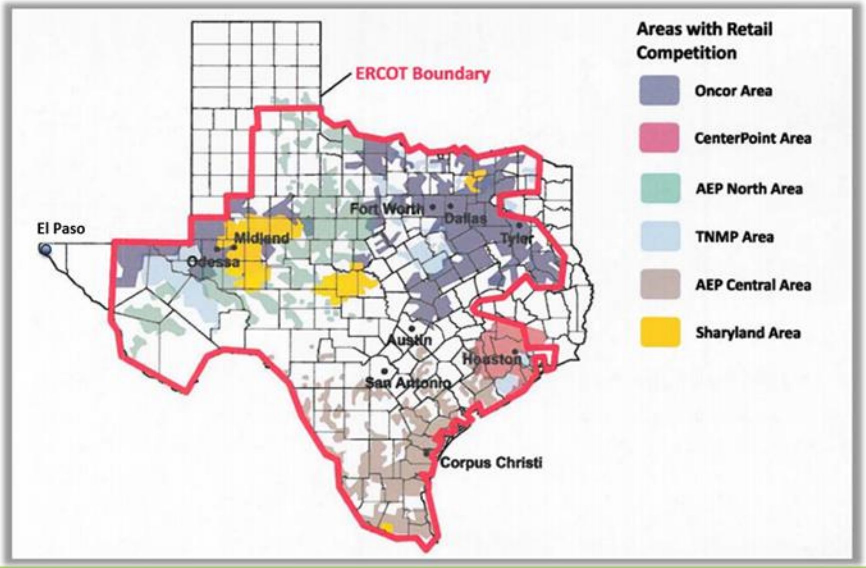
Compensation for rooftop solar PV in Texas today

Most Retail Electric Providers (REPs) in ERCOT -- with the exception of a few municipalities and retailers -- do not have programs that offer value to those who generate excess solar power. The Austin and San Antonio utilities provide cash rebates for rooftop solar installation.

Retailers that provide payback to roof-top solar in ERCOT:

Reliant Energy: Simple Solar Sell Back Plan (NEM).
TXU Energy: Renewable Buyback Program (credits for surplus renewable generation at a reduced rate)
Green Mountain Energy: Renewable Rewards Buy-back Program (NEM).
MP2: NEM for the Oncor and CenterPoint service areas.

ERCOT and Competitive Retail Areas



Municipalities that provide payback to roof-top solar in ERCOT:

Austin Energy: Value of Solar tariff that pays all generation from solar at a reduced rate
CPS Energy (San Antonio): NEM
City of Brenham: pays the net export generation at avoided cost rate

Sources and Notes:
Database of State Incentives for Renewable Energy. Retailers and municipalities' websites. The map is adapted from ERCOT, ERCOT Market Education, Retail 101.

Compensating DER in ERCOT

There are several methods that have been explored to make compensation for DER more accurate and economically efficient.

Net Energy Metering (NEM) -- Some states and cities including San Antonio have adopted NEM, in which customers' total DER generation is netted against their total electricity demand over some period of time.

Value of DER -- Another approach for compensating DER is explicit payment for the value they bring to the system (City of Austin).

Three-part rates – Some states use a three-part rate structure that is comprised of a customer fee, a per-kWh volumetric charge and a "demand charge," which is based on maximum kW demand.

However, each of these methods presents some practical and/or political challenges.

Compensating DER – Net Energy Metering (NEM)

Under NEM, customers' total DER generation is netted against their total electricity demand over some period of time.

- During hours when a customer's DER generates more than demand, the excess energy is credited against customer usage in hours when demand exceeds DER output.
- The netting of customer demand and DER output is usually done on a billing-cycle basis (typically monthly).
- Credit that is unused at the end of a billing cycle is often carried over to the next cycle.
- At the end of the year, any remaining credit is forfeited or paid out depending on the jurisdiction.

However, when NEM is combined with electric rates that charge customers a small monthly fee and a second per-kWh fee for energy consumed (ie. volumetric rates), system costs can be shifted from DER adopters to non-adopters.

States and cities are moving away from NEM

To address the cost-shift issue, many states have switched or are switching away from NEM. For example:

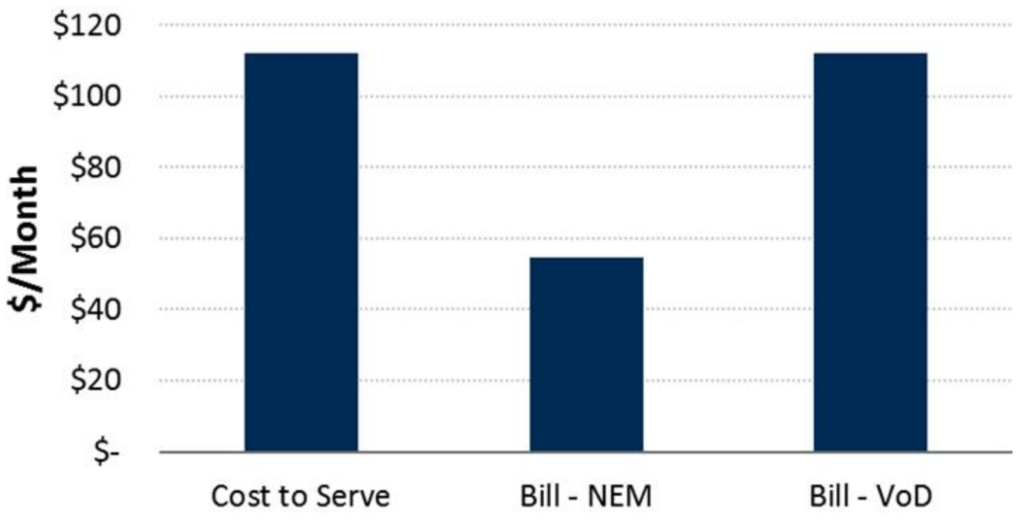
- Austin Energy[1] replaced NEM with a Value of Solar (VoS) tariff.
- Hawaii[2] ended NEM and replaced it with a new tariff that pays export at a lower rate than the retail rate.
- Oregon[3,4] is developing a VoS tariff to replace its NEM.
- New York[5] is moving away from NEM and replacing it with a "Value Stack" notion as part of Reforming the Energy Vision (REV). The Value Stack is essentially a VoD (in New York, it is termed Valuing Distributed Energy Resources or VDER).
- Minnesota is offering utilities a VoS alternative to NEM.[6] The Minnesota VoS is used for community solar, but the utilities have not adopted it for rooftop solar.

[1] Austin Energy, "2018 Value of Solar (VOS) Update," May 26, 2017.
[2] Hawaiian Electric, Customer Renewable Programs . Accessed on December 10, 2018
[3] PacifiCorp, "Resource Value of Solar Filing," Docket No. UM 1910, November 30, 2017.
[4] Portland General Electric Company, "Resource Value of Solar Filing," Docket No. UM 1912, December 4, 2017.
[5] State of New York Public Utility Commission, Order on Net Energy Metering Transition, Phase One of Value of Distributed Energy Resources and Related Matters, Case 15-E-0751 and Case 15-E-0082, March 9, 2017.
[6] Minnesota Department of Commerce, Division of Energy Resources, "Minnesota Value of Solar: Methodology," April 1, 2014.

Compensating DER – Value of DER (VoD)

Another approach for compensating DER is explicit payment for the value they bring to the system (Austin). This is called the Value of DER (VoD).

- In essence, the DER is considered a generator separate from the retail customer (home, commercial or industrial facility) and compensated for its output at a VoD rate.
- A well-designed VoD eliminates cross-subsidization by separating customer consumption from DER payment.



Components of a VoD tariff

A VoD tariff would have these four components:

- ***Real-time energy payments***. The tariff would not have numeric energy provisions. Energy would be paid at the wholesale price adjusted for losses. Storage charging would pay the wholesale price *adjusted for losses*.
- ***Ancillary services payments***. The tariff would not have numeric ancillary services provisions. Ancillary services would be paid at the wholesale price *adjusted for losses*.
- ***An avoided distribution component***, which would have three parts:
  - The first part would be for general avoidance of future distribution system upgrades. This would be available to all customers to the extent that they reduce the peak load on the distribution system.
  - The second part would be a locational factor for deferring specific distribution upgrades. This would be available in a limited number of high-value locations.
  - The third part would be a *charge* that the DER would have to pay *if* the DER requires an upgrade to the distribution system to accommodate its output. This part would be zero under most circumstances. Only if local DER penetration becomes very high might such a charge be necessary.
- ***An avoided transmission component***, which would have two parts:
  - The first part would be for general avoidance of future transmission system upgrades. This be available to all customers to the extent that they reduce the peak load on the transmission system.
  - The second part would be a locational factor for deferring specific transmission upgrades. This would be available in a limited number of high-value locations.

A VoD tariff is difficult and expensive to implement

Energy and ancillary services values should be adjusted for losses. Technology-specific distribution values should be adjusted for distribution peak coincidence factors. Technology-specific transmission values should adjusted for transmission peak coincidence factor and losses.

VoD Placeholder Values		
Component	Value	Notes
Energy	Locational real-time energy	Paid as earned or incurred
Ancillary Services	ERCOT ancillary services	Paid as earned or incurred
Base Distribution	$14/kW-year	Brattle Oncor Study
Locational Distribution	$0-$31/kW-year	Brattle Oncor Study
Distribution Cost	$0/kW-year	Calculated by the TDSP
Base Transmission	$36/kW-year	Brattle Oncor Study
Locational Transmission	$0/kW-year	Calculated by the TDSP

VoD is the most straightforward way to compensate DERs -- but likely the most difficult to implement. VoD calculations are complex, especially for important locational components. Moreover, a VoD does not work for EE and DR, which cannot be metered separately from the customers' demand.

Compensating DER - Three-part rates

Utilities in some states use a three-part rate for their residential customers, similar to rate structures used for commercial and industrial customers. Three-part rates have a customer fee, a per-kWh volumetric charge and a demand charge based on maximum kW demand.

- These rates distinguish between energy (kWh) and demand (kW) that align the cost to serve customers with usage.
- The customer's maximum kW demand theoretically affects the size of the substation and associated equipment needed to serve the customer.
- The distinction between energy and capacity is analogous to the distinction between energy and capacity provided by power plants: energy is a variable cost per kWh and capacity is a fixed cost per kW.

Three-part rates follow the important principle of cost causation under which customers pay for the costs they impose on the system. Utilities in twenty-two states offer three-part rates to their residential customers.

However, three-part rates are disfavored by Texas stakeholders. They expressed concern about the demand charge component and potential confusion for residential customers.

V. Increasing Visibility for DER – Nodal Pricing

ERCOT White Papers on DER

ERCOT has published two white papers on DER, highlighting the benefits and challenges of integrating DER into ERCOT's Bulk Electric System (BES).*

ERCOT is positive about the contribution of DERs in the future. ERCOT notes that transmission constraints such as those in the Rio Grande Valley and the Odessa oil fields might have received relief from DER (2015 White Paper).

* NOTE: ERCOT, Distributed Energy Resources (DERs), Reliability Impacts and Recommended Changes, March 22, 2017; ERCOT, ERCOT Concept Paper on Distributed Energy Resources in the ERCOT Region, August 19, 2015

ERCOT adapts to the emerging power system

In the emerging power system with more distributed generation, battery storage, energy efficiency and demand response, customers play an active role by generating their own power and/or actively managing their energy use.

If ERCOT had no visibility of DER, as DER grows it could make load forecasting less accurate and lead to increased load uncertainty.

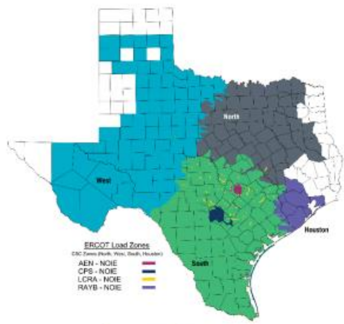
In anticipation of increasing DER penetration, both the Public Utility Commission (PUC) of Texas and ERCOT have begun tracking the growth in DER. ERCOT is working to map all registered (>1 MW) DER to the transmission system load.

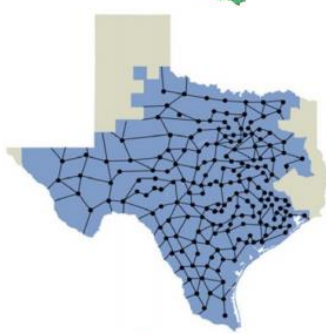
In the future, ERCOT could anticipate "net load" (load adjusted for DER output including excess output, and charging demand for storage), but ERCOT can only do this if it knows the portfolio of DER on the distribution system.

ERCOT is considering nodal pricing

ERCOT is currently considering a change (NPRR917) to settle at nodal prices, which would provide better price signals for DER and support reliability and efficiency.

Prices Received by Distributed Energy Resources





Current: Zonal Pricing

- DERs currently receive the zonal price.
- The Load Zone price is a weighted average of Locational Marginal Prices (LMPs) in the zone and does not fully reflect the local reliability need.

Future: Nodal Pricing

- Grid-scale resources that receive the locational price may have to overcompensate if nearby generation does not respond to local price signals.
- A LMP represents the value of energy at a specific location.
- Nodal prices better reflect the local reliability need.
- Registered DERs should receive a LMP in the future.

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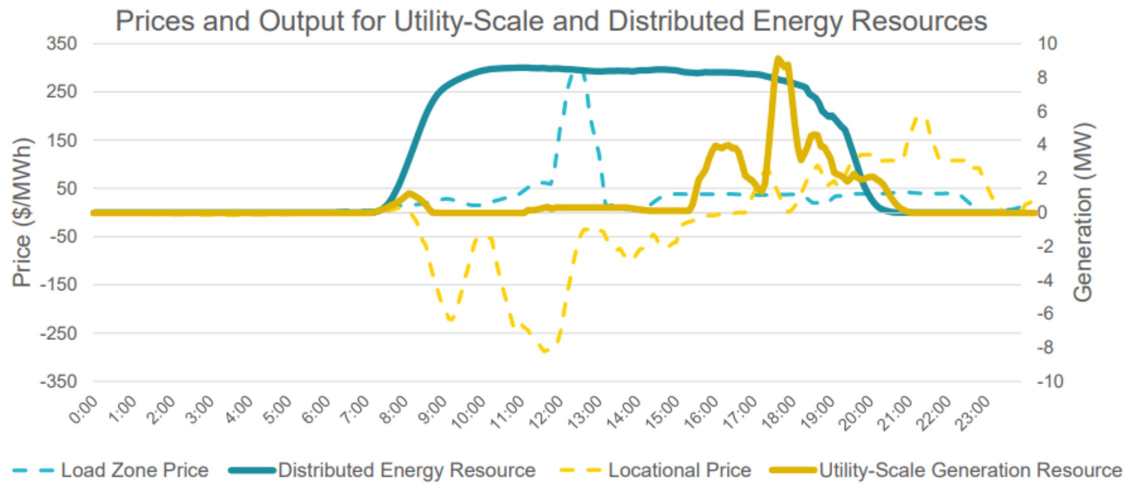
Source: ERCOT Emerging Grid Issues Briefing, November 18, 2018; http://www.ercot.com/mktrules/issues/NPRR917.

Nodal pricing can improve price signals

Giving DER the ability to respond more accurately to market price signals can further enhance the value of DER.

Zonal Pricing of DERs Results in Inefficient Price Signals



- Currently, a DER solar facility does not receive negative locational prices; instead, it receives the Load Zone price, which does not dip below zero.
- A grid-scale solar generation resource receives the LMP at its location, and in this example, lowers output accordingly when LMPs go negative.

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Source: ERCOT Emerging Grid Issues Briefing, November 18, 2018.

VI. DER in ERCOT – Issues for Further Study

DER in ERCOT – Issues for Further Study

Evaluate how time-variable pricing could better align the economics of various types of DER with system needs and costs.

- Consumers with rooftop solar would likely see a bill reduction impact for reduced consumption, since solar output is highest during high-priced afternoon hours.
- Consumers with battery storage could arbitrage between high- and low-priced hours.
- Consumers with small generators could tailor operation to high-priced hours to maximize value for themselves and the grid.

Explore ways to increase transparency and flexibility for market participants:

- Improve price signals so that DER can be located optimally.
- Explore solutions to manage when electric vehicles (EVs) charge their batteries and to harness EV batteries as energy storage assets.

DER in ERCOT – Issues for Further Study

Explore the implications of a three-tiered approach to integrating DER and other new technologies, as proposed by a Texas stakeholder under PUC's ongoing proceeding "Rulemaking to Address the Use of Non-Traditional Technologies in Electric Delivery Service." *

- ***Competitive market*** – support competition and customer choice, and let the market provide solutions to system problems.
- ***Non-wires alternatives*** – if the market is not solving a pressing problem, e.g. a system reliability problem, utilities should consider non-wires alternatives (NWAs) such as distributed generation, energy storage, EE/DR, or grid software and controls to defer or replace the need for traditional investments by reducing load at certain locations; moreover, utilities should be able to invest in NWAs on an equal regulatory footing with traditional infrastructure investments.
- ***Regulated solutions*** – if neither the market nor NWAs can solve a pressing problem, utilities can propose a regulated solution such as physical assets and non-traditional technologies including microgrids, DR and battery storage.

*Source: PUC Project No. 48023, Comments of Texas Advanced Energy Business Alliance, November 2nd, 2018.
http://interchange.puc.texas.gov/Documents/48023_7_998349.PDF

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Dr. Shavel is an energy economist with over 30 years of experience in the energy industry, specializing in the economics and operations of the U.S. electric power system, generation and transmission investment, and environmental strategy. He has performed work for a wide range of clients, including generation and transmission companies, natural gas pipelines, marketers, developers, industry research groups, and as federal agencies. Recently he co-authored a study for the Texas Clean Energy Coalition on the future of renewable and natural gas generation in ERCOT.

Dr. Shavel has broad experience developing models of North American power systems, including the Integrated Planning Model by ICF International. He has also directed significant assignments for major electric utilities, independent transmission companies, RTOs, independent power producers and private equity on matters such as coal plant retirements, fuel price forecasting, the benefits of new transmission lines and power plant valuation. Dr. Shavel has testified before the Federal Energy Regulatory Commission (FERC), state regulatory agencies, and the Ontario Energy Board. Prior to joining Brattle, Dr. Shavel was a Vice President at Charles River Associates (CRA). While at CRA, he led the development of the National Energy and Environment Model (NEEM) and contributed to its integration with the Multi-Region National Macroeconomic Model.

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Dr. Faruqui specializes in smart grid strategies involving the consumer. His expertise includes demand forecasting, innovative rate design, energy efficiency, demand response, advanced metering infrastructure, technology assessment, and cost-benefit analysis.

He has worked for nearly 150 clients on five continents. These include electric and gas utilities, state and federal commissions, independent system operators, government agencies, trade associations, research institutes, and manufacturing companies.

Dr. Faruqui has testified or appeared before commissions in Alberta (Canada), Arizona, Arkansas, California, Colorado, Connecticut, Delaware, the District of Columbia, FERC, Illinois, Indiana, Kansas, Maryland, Minnesota, Nevada, Ohio, Oklahoma, Ontario (Canada), Pennsylvania, ECRA (Saudi Arabia), and Texas. He has presented to governments in Australia, Egypt, Ireland, the Philippines, Thailand and the United Kingdom and given seminars on all 6 continents.

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Dr. Yang is currently a senior associate in the Utility Practice Area of Brattle. Her experience is focused on developing and using economic models to conduct the economic and policy analysis of energy and environmental issues in the energy industries with a focus on the power and natural gas sectors. She has performed the economic and policy analysis of the power system and generation technologies to consult energy industry companies for integrated operation planning and environmental strategies as well as the impact of shale gas production on the electric sector and the whole economy.

Before she joined Brattle, she worked for CRA, where Dr. Yang led the modeling effort of MRN-NEEM (Multi-Regional National model-North American Electricity and Environment Model). Prior to joining CRA, Dr. Yang worked at MIT Energy Initiative during her postdoctoral research where she participated in a large interdisciplinary MIT study entitled "The Future of Natural Gas" and led the quantitative analysis of the impacts of a US climate policy on natural gas consumption in the power sector by employing the MARKAL model and contributed to the chapter, "Demand for gas in the power sector."

VII. Appendix

The Legacy Power System

The generators have four main characteristics that provide instantaneous power to customers when needed.

- Provide capacity (MW or kW).
- Provide energy (MWh or kWh).
- Change power levels quickly to follow variations in aggregate customer demand.
- Support the required voltage to ensure reliable supply to customers.

The key parameters of generators that support reliable delivery of power are:

- Capacity in terms of maximum instantaneous output (MW).
- Energy in terms of MWh.
- Ramping capability in terms of how quickly output can be changed.
- Reactive power capability (kVA) to support voltage on the transmission and distribution systems.
- Locational constraints.

The Legacy Power System

The transmission and distribution subsystems are sized to carry power from generators to customers. The main elements of the transmission and distribution subsystems are power lines that move power from place to place and transformers that adjust voltage levels.

Historically, as customer demand increased over time more power plants were added and the transmission and distribution subsystems were expanded to move the additional power to customers. That pattern is now changing.

ERCOT has a robust wholesale market

ERCOT's primary responsibility is to provide low-cost, reliable wholesale electric service across the entire ERCOT footprint. ERCOT provides this function for about 90% of customer demand in Texas.

ERCOT operates a series of markets for wholesale electric products. The products are:

- Hourly day-ahead energy.
- Real-time energy on a five-minute basis.
- Ancillary services products that are needed so that electric supply and demand can be matched almost instantaneously.

The ERCOT market-clearing software produces prices for all of these products. Energy prices are locational, reflecting transmission constraints on the ERCOT grid. The locational prices reflect the value of energy either consumed or produced at any location on the grid.

Cost of electric service and cost recovery

Electric service has two broad cost categories in ERCOT:[1]

- Production of electricity.
  - Fuel.
  - Variable O&M.
- Transmission and distribution.
  - Fixed O&M.
  - Capital costs.

Production costs (from the customer perspective) are entirely variable. Transmission and distribution costs are almost entirely fixed.

The utilities (AEP, Oncor, CenterPoint and Texas-New Mexico Power) are responsible for billing customers for transmission and distribution. This is done in two ways:

- Large customers have a monthly *fixed* charge for their connection and meter, and a *per-kW* charge for distribution and transmission.
- Small customers including residential users have a *fixed* charge for their connection and meter, and a *variable* charge for distribution and transmission (per kWh of usage).

[1] ERCOT has an energy-only market. The costs of electric service that customers see are only variable costs and do not include a fixed component for generation capacity as it would in other US markets. There are also costs for billing and metering.

Cost of electric service and cost recovery

The major components of fixed cost are:

- Annual fixed costs for investment in infrastructure, labor and maintenance.
- Allowed rate of return on “ratebase,” where ratebase is the original cost of the transmission and distribution assets minus accumulated depreciation.

Rates are set by the PUCT so that the total dollars recovered approximately cover utility costs. Utilities bill REPs for the cost of transmission and distribution service to serve the REP’s customers.

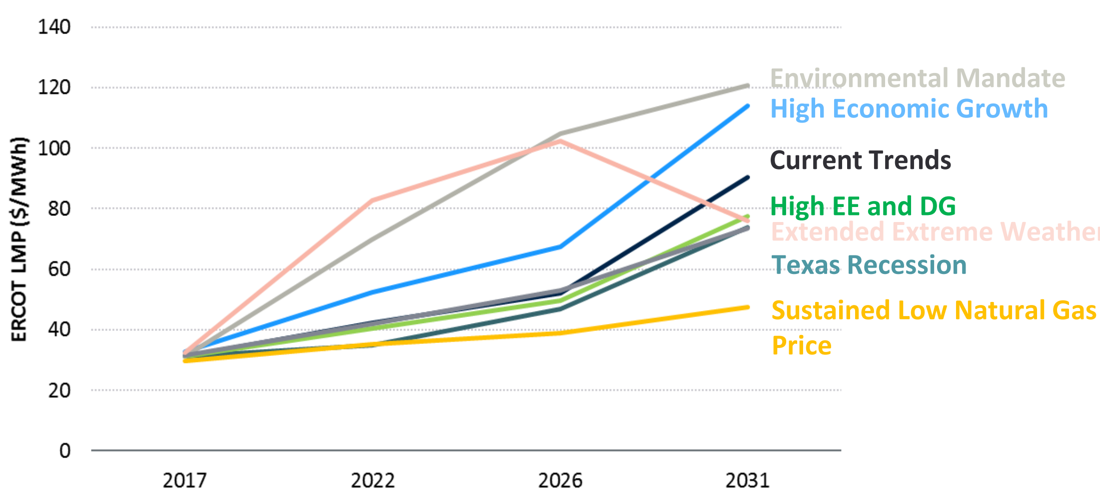
The REPs contract with customers to provide electric service. They buy energy on their customers’ behalf and pass through the regulated cost of the transmission and distribution service. They are not price-regulated by the PUCT.

Energy values should not use long-term projections

Projection-based compensation can over- or under-compensate DER.

- For example, if DER were paid based on the average long-term prices forecast in the 2016 LTSA under Current Trends, compensation would be $53/MWh. But if the future path followed the Environmental Mandate scenario, the average price would be $82/MWh, in which case DER would be under-compensated.
- Similarly, DER might be over-compensated if the future path followed the Sustained Low Natural Gas Prices scenario.

ERCOT Energy Prices Forecast in 2016 Long-Term System Assessment



Source: ERCOT, 2016 Long-Term System Assessment for the ERCOT Region, 12/26/2016

Calculating T&D benefits of DER – Deferral Analysis

DER can delay or avoid T&D investment. DER might avoid an upgrade entirely, but that is unlikely unless load growth is zero or negative.

If DER delays T&D investments, it defers the expense to a later date, resulting in a system savings. The appropriate way to estimate such T&D deferral benefits is to determine how DER installations might defer or avoid future T&D investment. The T&D cost savings is the time value of the deferred T&D expenditure.

DER should be compensated at the appropriately discounted future value of the T&D deferral. The longer the deferral period, the larger the benefit.

To do this calculation for a specific DER or a group of similarly situated DER installations, one would:

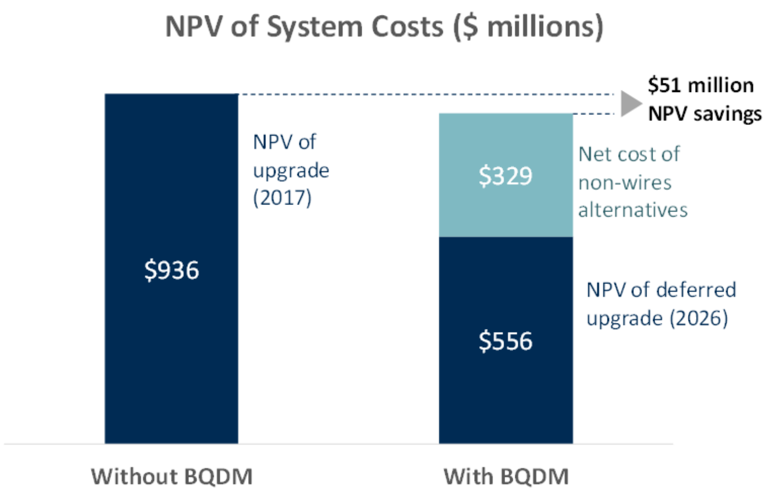
- Determine the T&D elements that could be deferred or avoided entirely, and their cost;
- If a deferral, determine the duration of the deferral (years); and
- Estimate the present value of the deferred/avoided element.

If the DER require an upgrade to the T&D system to accommodate it, a similar analysis could be performed.

ConEd BQDM project's deferral savings

Brooklyn Queens Demand Management (BQDM) project is 50 MW of demand-side resources and storage to delay a very expensive ($800 million) substation upgrade.

- This is often described as a $200 million investment that avoids a $1 billion substation, but it is actually an investment that *delays* the substation need. It does not save $800 million.
- The correct calculation is to compare the substation's cost in the short term with the $200 million additional investment PLUS the time value money for delay the $1 billon substation invest (for about nine years).
- The total investment over time is greater with BQDM project, but the major capital investment is shifted into the future, which results in a $51 million present value savings.



Note: cost of non-wires alternatives is net of associated bulk system benefits (e.g. avoided generation capacity and energy costs).

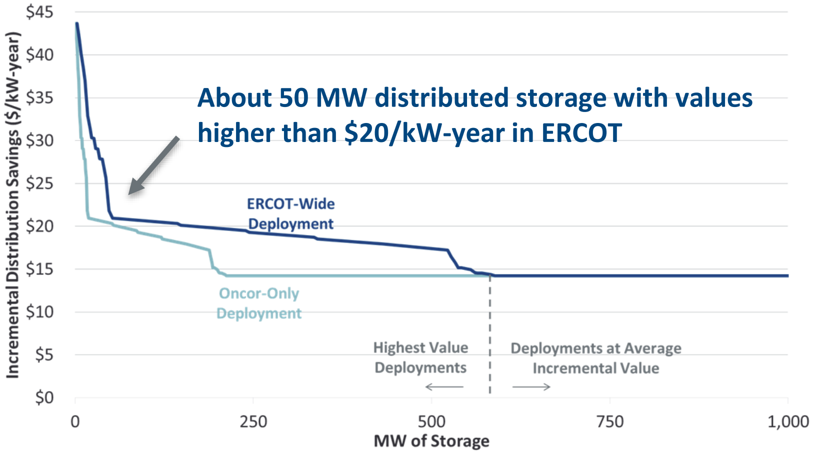
Source: NY DPS website: http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7B8EE6660B-304E-4B49-87DF-7DF3D6A9B623%7D

T&D savings for distributed storage are location specific

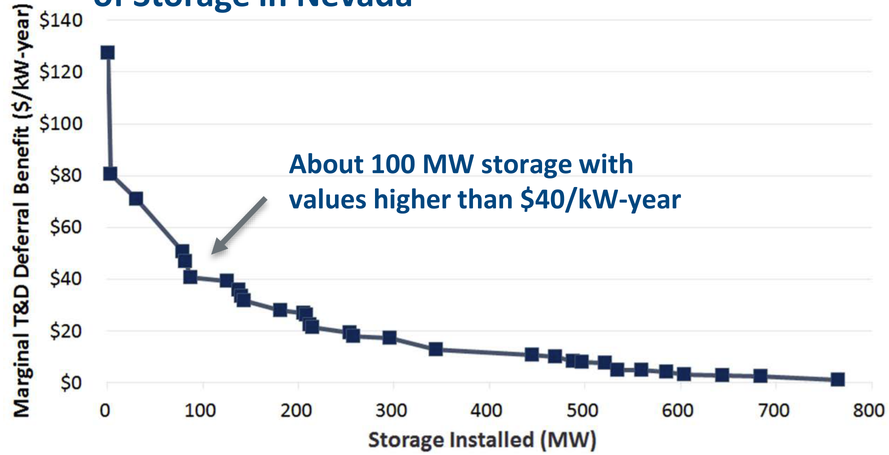
Many researchers have found distribution savings to be small on average, but savings can be quite large for strategically located DER.

Prior Brattle studies for Oncor and a 2018 study for the state of Nevada identify high-value opportunities for distributed storage assets, but the opportunities were limited.

Distributional Deferral Value of Storage in Texas



Transmission and Distribution Deferral Value of Storage in Nevada



Source: Brattle (2015), The Value of Distributed Electricity Storage in Texas

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