Doosan GridTech®

UNDERSTANDING THE VALUE OF SOLAR IN COMPLEX ENERGY SYSTEMS

The Rise of a System-Levelized Cost of Energy (S-LCOE)

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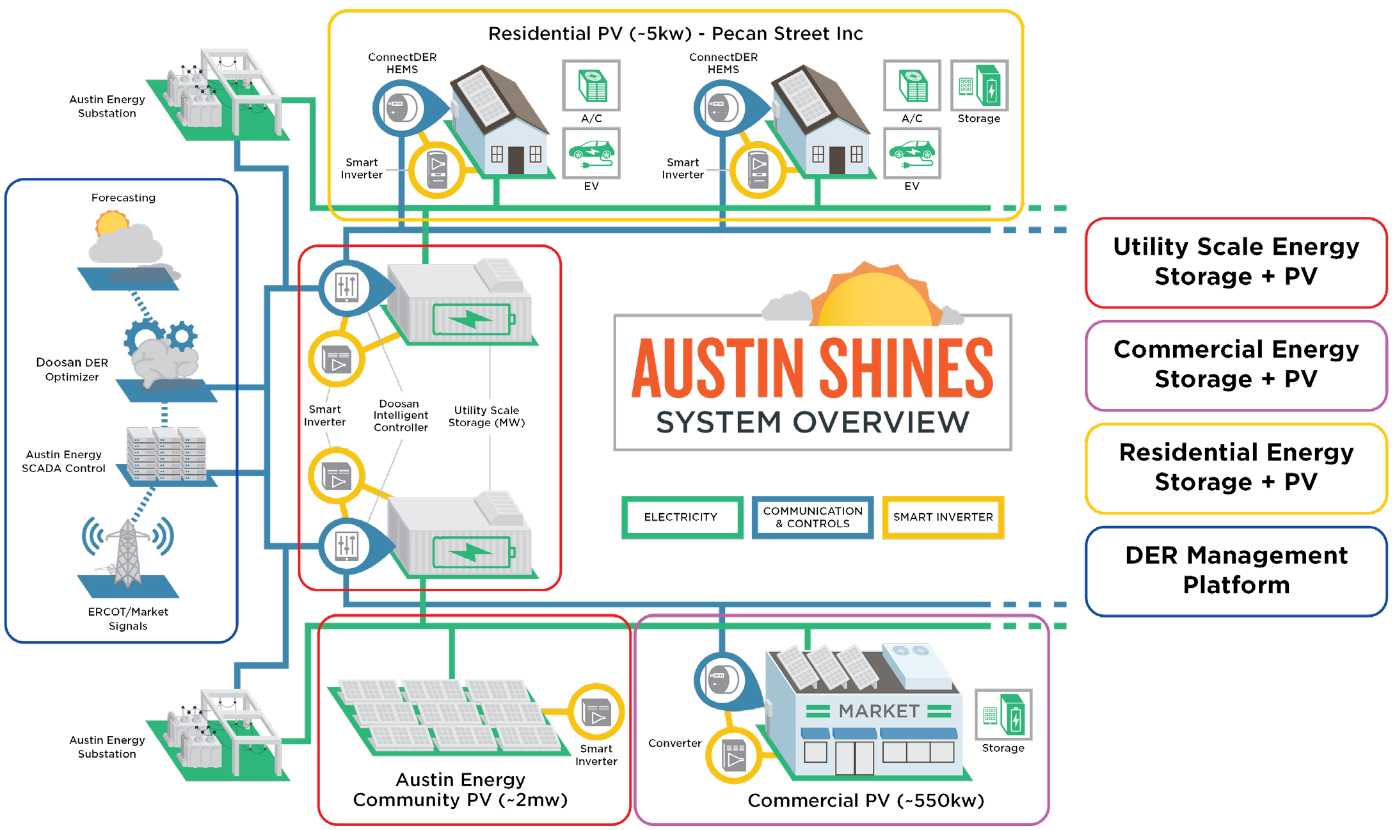
CONCEPTUAL OVERVIEW

The goal of the Austin SHINES program is to demonstrate a grid solution that offers a credible pathway to a System-LCOE of less than $0.14/kWh for energy delivered to load by 2020. In 2016, the US Department of Energy's SunShot program awarded Austin Energy the largest grant in its SHINES program to create this new measure and evaluate its potential as an industry standard. SHINES is an acronym for Sustainable and Holistic Integration of Energy Storage and Solar PV.

While pursuing that objective, Austin Energy and Doosan GridTech created a distributed energy resources (DER) management platform that maintains grid reliability and power quality. It also enables energy to be delivered at the lowest possible costs when there are high penetration levels of distributed solar PV. Austin Energy, Doosan, and their partners have designed and installed more than three megawatts of distributed storage, smart solar inverters, a DER control platform, and other technologies utilizing customer and utility locations and multiple aggregation models. Design and operation of this system require the coordination of numerous diverse devices that each contribute to reliability, power quality, and efficiency in an integrated fashion. No individual asset is isolated but is instead a dependent and supportive element of a holistically integrated system. Evaluating a single asset in isolation cannot fully measure the potentially negative impacts of this asset or the actual benefit it brings when working together with other assets. Two non-adjacent distribution circuits (Kingsbery and Mueller) were used in this study.



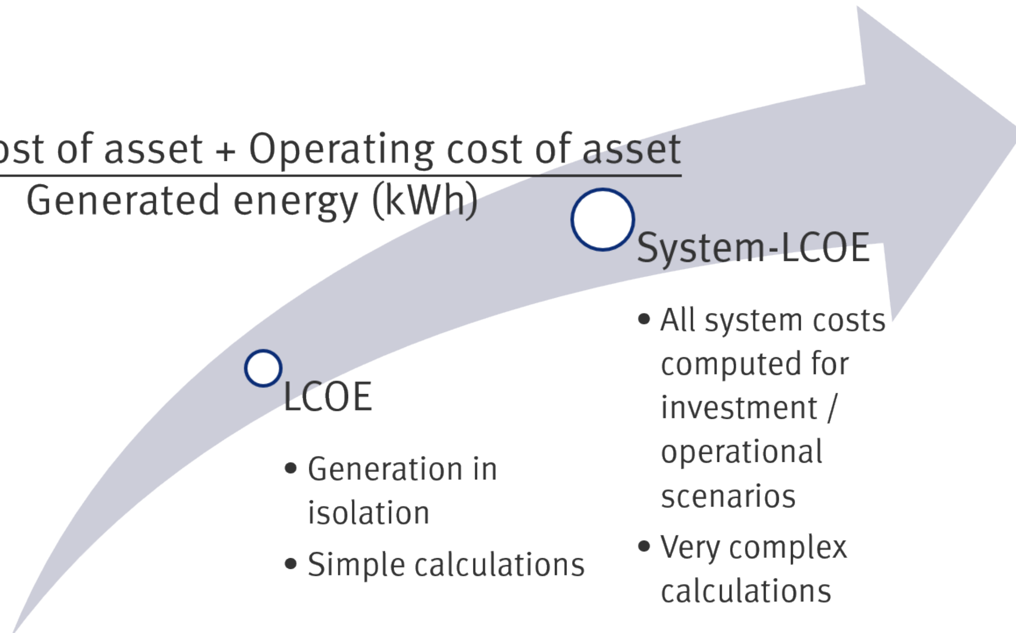
As a design metric, the system-levelized cost of energy (S-LCOE) can solve this issue by including the combined costs and benefits of all assets working together within the defined system boundary to reliably serve load. In the Austin SHINES system, S-LCOE is specifically used to calculate the differential value of integrated DER management, as compared to the value of uncoordinated DERs.

LCOE vs. System-LCOE

LCOE: Levelized Cost of Energy

- Measures the cost of producing a unit of energy over the lifetime of a generating asset
- Estimates the present value of capital and operation & maintenance (O&M) costs of an asset over its lifetime
- Allows comparison of different generating assets
- Considers generation 'in isolation'

$$LCOE = \frac{\text{Capital cost of asset} + \text{Operating cost of asset}}{\text{Generated energy (kWh)}}$$



System-LCOE:

- Measures the cost of all assets working together within the defined system boundary to reliably serve a unit of load demand
- Encompasses the holistic, system-level costs and benefits of all resources
- Enables resources to be evaluated based on their ability to support an efficient and low-cost integrated grid ecosystem

$$\textit{System-LCOE to Serve Load} \text{ (\$/kWh)} = \frac{\left[\begin{array}{c}\text{Capital cost of}\\ \text{all equipment}\\ \text{within system}\\ \text{(\$)}\end{array}\right] + \left[\begin{array}{c}\text{Operating cost}\\ \text{of all}\\ \text{equipment}\\ \text{within system}\\ \text{(\$)}\end{array}\right] + \left[\begin{array}{c}\text{Net value of energy,}\\ \text{capacity, and}\\ \text{services that cross}\\ \text{system boundary}\\ \text{(\$)}\end{array}\right]}{\left[\begin{array}{c}\text{All load served within}\\ \text{the system (kWh)}\end{array}\right]}$$

METHODOLOGY

Critical Model Development

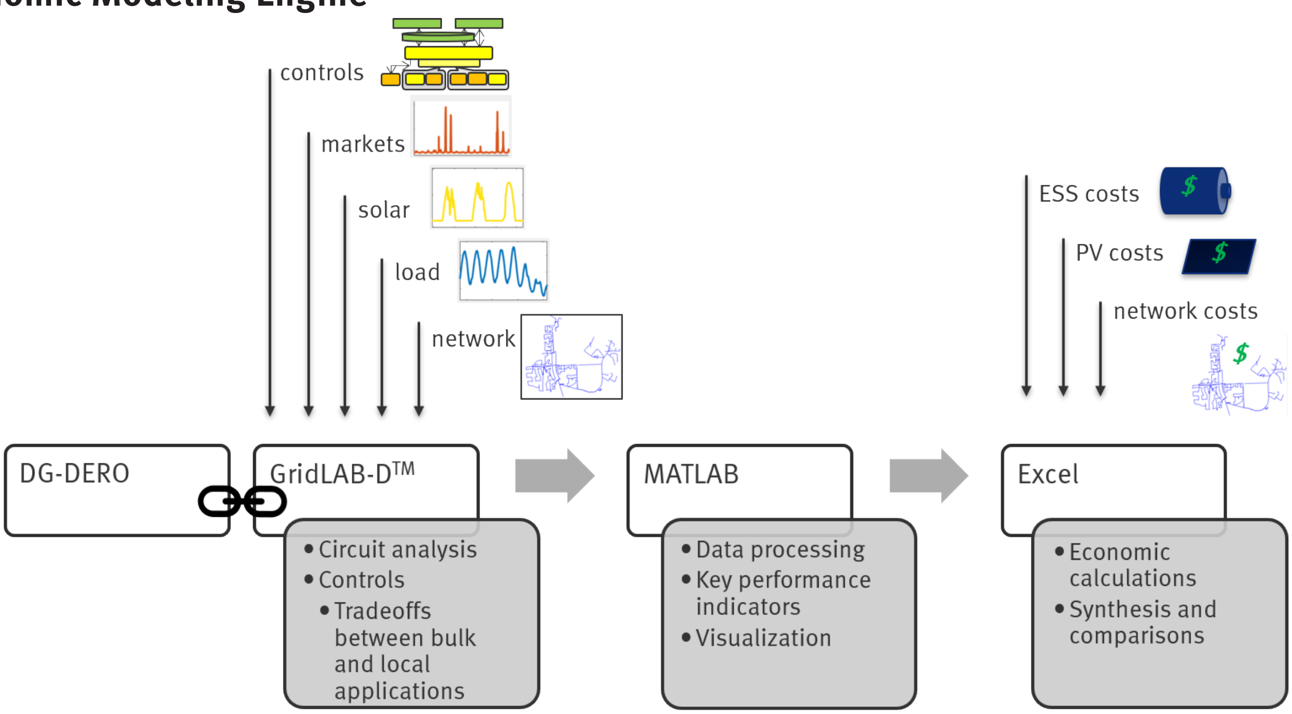
Developing a circuit model that offers a close-to-reality representation of the actual distribution circuit system is crucial to the accurate calculation of System-LCOE. All Austin SHINES assets are hosted on five distribution feeders which are supplied by two different substations, and hence, can be assumed as two separate circuits. In the first stage of circuit analysis, detailed network models of these two circuits were developed in GridLab-D, a quasi-static time-series distribution system simulation tool which models electric characteristics and controls of each asset. The base circuit models included all existing DERs. The next stage added highly granular historical time-series data to the base circuit models to develop dynamic models capable of capturing time-variable quantities of the actual circuits — such as consumption patterns, solar generation profiles, real-time and day-ahead market prices, and dynamic behavior of energy storage.

Economic Modeling

The next step to calculate System-LCOE was developing an economic model to assess the economics of the distribution circuit. This economic model was used to analyze the value of control applications to be implemented in the Austin SHINES project. These control applications were divided into three categories:

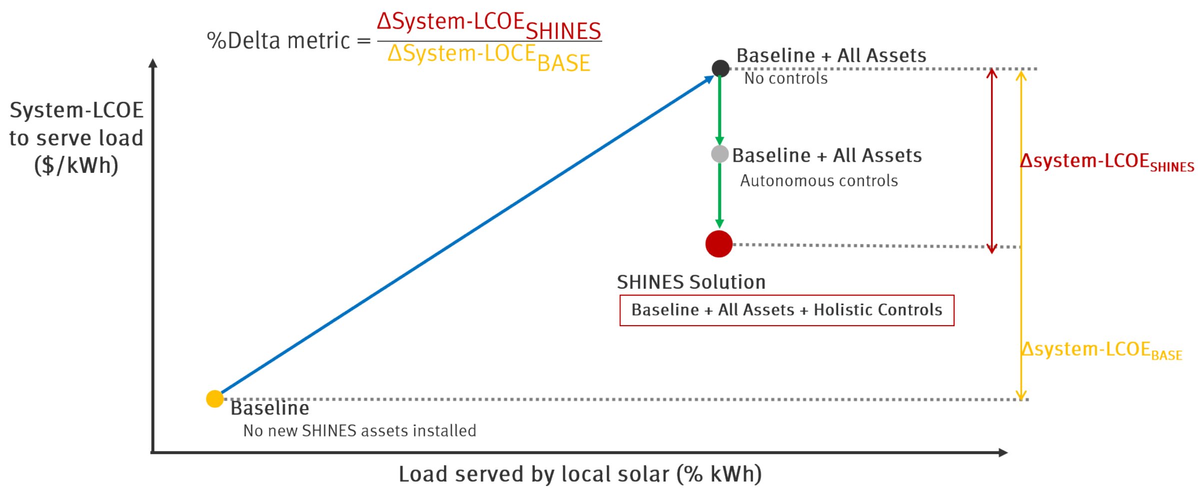
- Bulk market application: peak load reduction, real-time price dispatch, and energy arbitrage
- Local technical applications: voltage support and congestion management
- Customer-focused application: demand charge management

Economic Modeling Engine



How System-LCOE Changes with Solar Penetration and DER Control Strategy

The plane of Austin SHINES below indicates the baseline (pre-SHINES) distribution system that operates at a certain System-LCOE and has a certain solar penetration. The solar penetration of baseline MU and KB circuits are 5% and 1%. To increase the solar penetration, solar and energy storage assets need to be added to the baseline circuit. These new assets come at a cost (capital, O&M, communications, and control costs) and therefore, System-LCOE increases as the solar penetration increases. Ultimate System-LCOE at higher penetrations of solar depends on the effectiveness of DER controls.



Within the context of Austin SHINES, three control strategies with different levels of intelligence and complexity are defined:

- No control (noco) which involves very rudimentary controls essential for basic operation of the asset;
- Autonomous control (auco) which introduces local intelligence to the assets and enables them to make locally-optimal decisions, and;
- Holistic control (hoco) which involves a central brain (i.e., DER fleet manager) which has a global and holistic approach and optimizes value over assets and applications.

Asset	noco (rudimentary)	auco (local intelligence)	hoco (optimized)
Utility-Scale ESS	Fixed-schedule based on average LMP prices	Load following	ERCOT Market Applications • Peak Load Reduction (PLR) • Real-Time Price Dispatch (RTPD) • Energy Arbitrage (EA)
Commercial ESS	Fixed-schedule based on TOU pricing	Demand Charge reduction (DCR)	DCR ERCOT Market Applications • Peak Load Reduction (PLR) • Real-Time Price Dispatch (RTPD) • Energy Arbitrage (EA)
Residential ESS	Fixed-schedule based on TOU pricing	Maximizing self-consumption (i.e. minimizing PV backfeeding)	ERCOT Market Applications • Peak Load Reduction (PLR) • Real-Time Price Dispatch (RTPD) • Energy Arbitrage (EA)
Community PV	unity PF	unity PF	unity PF
Residential PV	unity PF	unity PF	unity PF

RESULTS & CONCLUSIONS

Final analysis and conclusions on the Austin SHINES program's performance will be presented to the US Department of Energy at the close the project's demonstration stage in October 2019. At that time, the analysis of the newly-formed System-LCOE metric will examine various asset (solar & storage) deployment scenarios and ultimately determine the optimal mixture of assets with the smallest S-LCOE. Presently, early-stage results are encouraging among nearly a dozen deployment scenarios. As an example, two deployment scenarios in the MU circuit are demonstrated below using the following assumptions:

- Both scenarios have 25% solar penetration by energy, all distributed, and
- Both scenarios have 4MWh of storage deployment (2-hr batteries regardless of type)

The following table shows the mix of energy storage system deployed in each scenario:

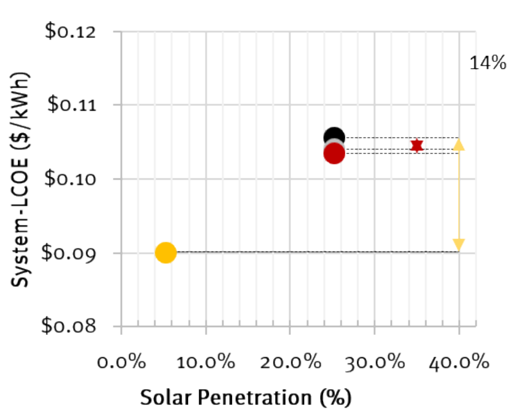
Scenario	Solar Penetration (%)	Residential solar (MW)	Community solar (MW)	Utility-scale ESS (MWh)	Residential ESS (MWh)	Commercial ESS (MWh)
1	25	4.9	0	4	0	0
2	25	4.9	0	2	1	1

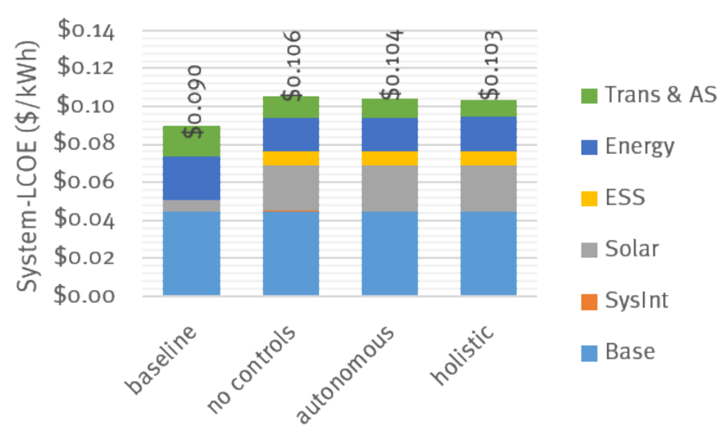
Scenario 1

MU system with 25% distributed solar and utility-scale ESS only
Utility-scale ESS deployment 2MW/4MWh (2 0.99MW/2MWh batteries)

Results:

- Holistic control has the smallest System-LOCE followed by autonomous and no controls
- Energy storage brings significant saving in Trans & AS costs through Peak Load Reduction application





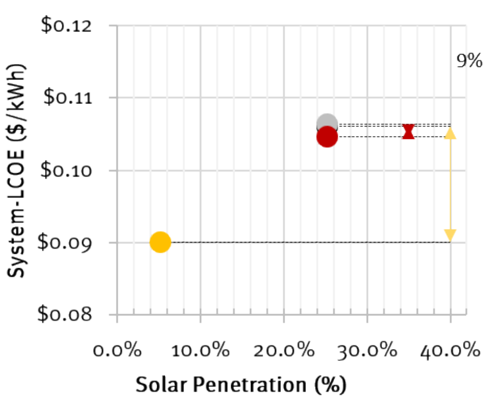
Scenario 2

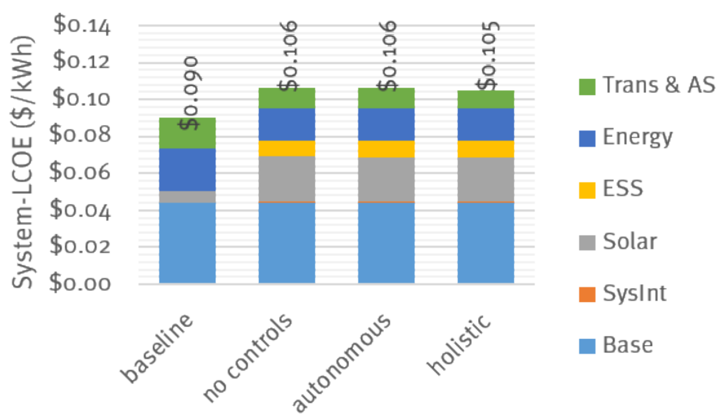
MU system with 25% distributed solar and a mixture of ESS deployment strategies with more weight given to utility-scale storage

- Utility-scale ESS deployment 0.99MW/2MWh
- Residential ESS deployment: 0.5MW/1MWh (125 4kW/8kWh batteries)
- Commercial ESS deployment: 0.5MW/1MWh (14 36kW/72kWh batteries)

Results:

- Holistic control has the smallest System-LCOE followed by no controls and autonomous
- No control has a smaller S-LCOE compared to autonomous control
    - ◊ *more complex control does not always yield better results in terms of S-LCOE*
- Energy storage brings significant saving in Trans & AS costs through Peak Load Reduction application
- Compared to scenario 1, scenario 2 has a larger S-LCOE, since bulk energy storage is currently cheaper than distributed energy storage.





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