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Docket Number:	16-IEPR-03
Project Title:	Environmental Performance of Electricity Generation System
TN #:	214639
Document Title:	The Emerging Clean Energy Economy
Description:	The Power Grid of the Future: Choice, Innovation, Opportunity, and Challenge
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Organization:	Southern California Edison
Submitter Role:	Public
Submission Date:	12/5/2016 4:10:00 PM
Docketed Date:	12/5/2016

The Emerging Clean Energy Economy:

Customer-Driven. Modernized. Reliable.

The Power Grid of the Future: Choice, Innovation, Opportunity, and Challenge

Amidst the profound shift underway in the electric power industry, today's customers are increasingly seeking choice in how they manage their energy. They are adopting distributed energy resources (DERs)—rooftop solar, onsite energy storage, electric vehicles, and energy management systems—to achieve cost savings, cleaner energy, conservation, and enhanced reliability. In response, the industry has begun an era of reinvention to enable these choices and create a clean, reliable energy future.

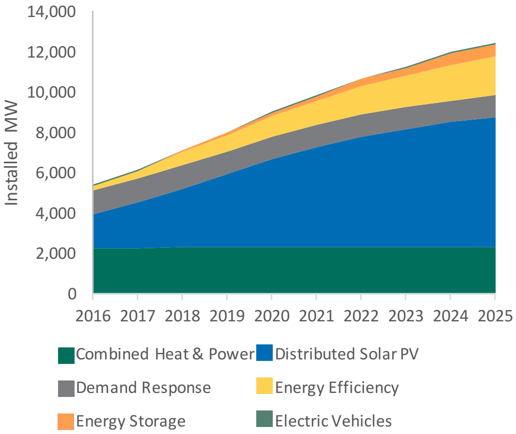
California is at the forefront of the power system transformation toward a cleaner, more diverse future with reduced carbon emissions. The state is home to 50 percent of the nation's private solar systems—more than half a million businesses and homes.[i] It boasts more than 200,000 plug-in electric vehicles (PEV)—40 percent of the nation's PEV sales—with a goal of 1.5 million by 2025.[ii] With proper support, DERs will not only benefit individual customers, but also could contribute significantly to local economies, clean energy, and grid resiliency (Figure 1).

The path suggested in this report leads to a modern electricity distribution grid and enhanced utility capabilities that will be vital to facilitating these choices and helping customers maximize their investments—while improving the reliability and affordability of the grid for everyone. Decisions made now on how to embrace this change will have profound implications for how the energy grid adapts to meet consumer needs and reduce carbon emissions for the rest of the twenty-first century.

Harnessing the potential of distributed energy resources

To facilitate the transformation, the local power grid must become a plug-and-play platform that integrates an ever-growing set of DER technologies.[iii] By connecting

Figure 1:
DER Forecast in Southern California Edison Territory



DER penetration could more than double in SCE territory over next decade.

to this platform, DER owners access a grid that supports their needs as customers and markets that increase the value of their investment. Maximizing this potential for all customers requires a thoughtful approach that:

- **Modernizes and reinforces the grid** and its operations to improve reliability and integrate distributed resources and other carbon reducing technologies;
- **Connects DERs to markets** that provide new revenue opportunities; and
- **Transitions to customer rate designs and DER programs** that better reflect the benefits and costs of distributed resources.

Modernizing and reinforcing the grid will be critical for customers seeking to adopt DERs and connect to the grid—quickly and with minimal hassle. Utilities must anticipate future DER growth and reinforce local grids to accommodate these new resources. Once connected, clusters or concentrations of distributed resources can quickly complicate grid operations. Grid operators need advanced sensors, communications, and automation so they can see what is happening in real time, minimize disruptions, and maintain reliability. To meet these challenges, utilities will expand their capabilities as Distribution System Operators (DSOs) that plan and manage a modernized plug-and-play grid, ensuring that all customers receive safe, reliable, clean energy, while seamlessly integrating rapid growth in distributed resources.

"...utilities will expand their capabilities as Distribution System Operators (DSOs) to plan and manage a plug-and-play grid..."

Connecting DERs to markets and new revenue opportunities can encourage innovative new markets and creative solutions that expand customer choice and benefit the grid.[iv] Three potential areas include:

- **Wholesale:** DSOs will ensure that DERs can connect to wholesale markets to sell services that reduce the need for new large-scale generation, while still maintaining local reliability.
- **Distribution:** DERs could receive compensation for providing location-specific services to the distribution grid, including the deferral of traditional grid upgrades.
- **Third party markets:** the distribution grid platform could enable markets for energy transactions between customers or marketplaces for new products and services.

Coupled with declining prices of DERs, these markets could eventually eliminate the need for subsidies and administratively-determined tariffs. DSOs will need to work with resource providers and other stakeholders to shape markets and distributed solutions that support the grid.

Finally, to maintain affordability for all customers, **rate designs and programs must transition to share the benefits and costs** among customers who deploy DERs to meet a portion of their energy needs and those who do not. Rates should account for the fixed costs of the grid so all customers, including DER owners, pay for access to the modernized and reliable distribution grid and the critical service it provides.[v] DER owners should receive compensation based on the value at the time and location of the services they deliver.

These massive changes to the grid and markets will take time—possibly more than a decade—to accomplish. But, if utilities, regulators, and distributed energy providers come together now with a sense of urgency, the foundation developing now will be established by the turn of the decade: with functioning markets for DERs, a modernized grid in priority locations, informed customers, proven resource providers, and reduced carbon emissions. Underpinning this, utilities will evolve to become facilitators of customer choice and the clean energy economy by unlocking the benefits of DERs while enhancing the reliability critical to everyone.

1. A modernized grid—essential to improving reliability and enabling distributed energy resources

Customer adoption of DERs can quickly alter the makeup of the electric grid. New devices impact system operations, requiring planners to adjust their forecasts and upgrade plans accordingly. Although independent system operators often run transmission systems and dispatch thousands of resources, the distribution system is more dynamic, fluid, and complex. DSOs will interact with hundreds of thousands—even millions—of distributed resources, and coordinate between control rooms and field crews in real-time to manage new markets and grid operations simultaneously. Utilities already perform many of these functions and have the scale and capability to integrate DERs into the planning, development, and operations of a modernized distribution grid.

"DSOs will interact with hundreds of thousands—even millions—of distributed resources, and coordinate between control rooms and field crews in real-time."

With this accelerating pace of change, a DSO must improve customers' ability to connect devices while ensuring the grid is prepared to operate reliably and safely with this increased level of complexity.

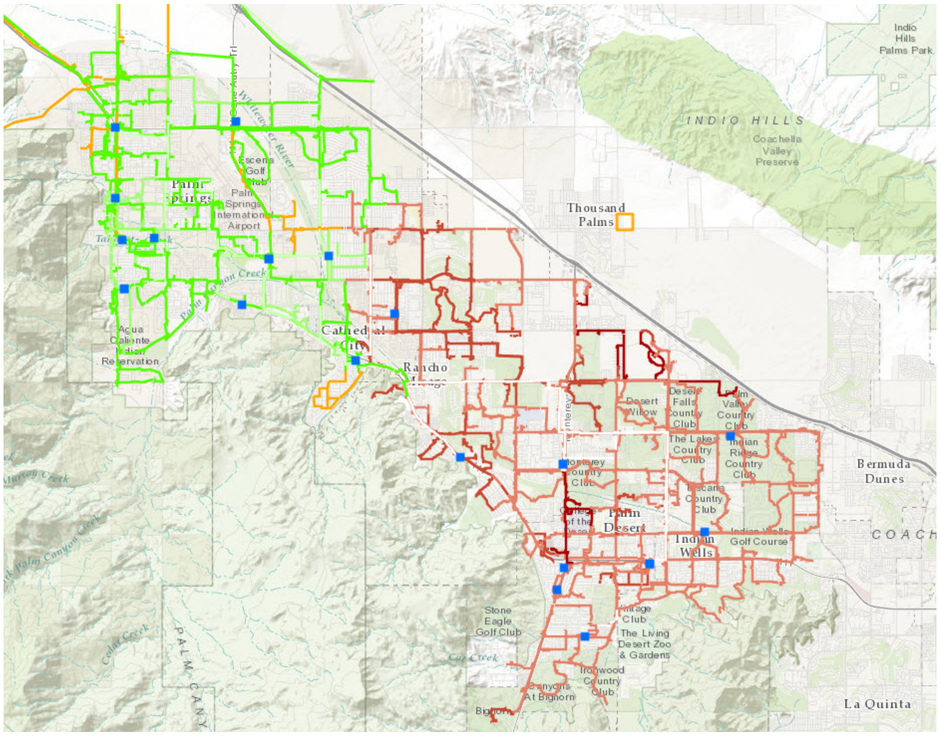
Connecting with ease

As DER penetration increases, certain places on the distribution grid will become constrained and unable to absorb more distributed resources.[*] [vi],[vii] These potential limitations must be addressed proactively, to avoid some customers facing extended waits and higher costs for interconnecting new devices. Ensuring that customers can connect new devices with ease will require the DSO to:

- **Upgrade its ability to forecast DER adoption and performance** with much greater granularity and accuracy. DSOs need enhanced analytics to understand the impacts of

[*] In California, utilities are processing thousands of new customer solar interconnection applications every month.

Figure 2: Sample DER Hosting Map in SCE Territory



Estimated amount of DER the distribution circuitry can accommodate without upgrades. Green areas can accommodate higher MW, and red areas accommodate less MW.

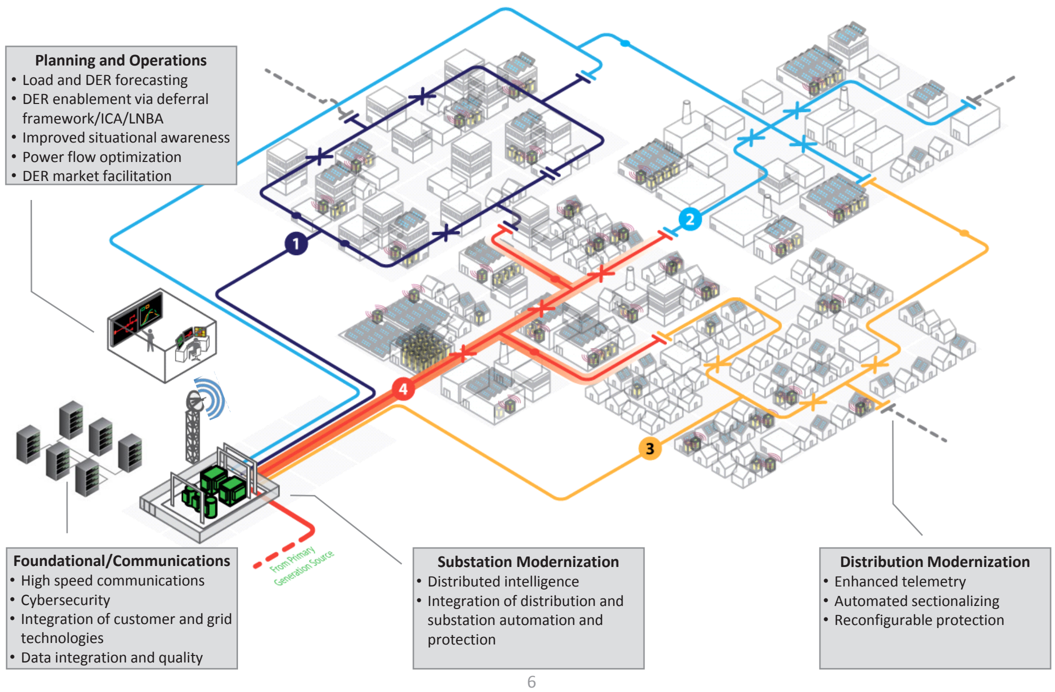
distributed resources on reliability and power quality, and new tools to assess the grid's capacity to integrate DERs.

- **Reinforce the local power network** to ensure that customers can adopt DERs in more locations and without delays. Connecting more DERs to constrained circuits without reinforcement may threaten reliability and flexibility (Figure 2). In many cases, these upgrades accelerate work to address aging infrastructure.
- **Ensure DER adoption and interconnection are a seamless process.** Procedures for interconnection must be simplified. DSOs will publish data to help customers understand how to connect easily and at lower costs.

Making the power network more flexible and resilient

In 2015, Southern California Edison operators performed over 22,000 switching procedures to reconfigure or isolate portions of distribution circuits. As DERs play a more prominent role on the grid, these operations will become more challenging. Human operators will struggle to keep up with the increasing speed and complexity of information flow, analysis, and decision-making. Instead of managing one-way power flows from a few large generators connected at transmission voltage, operators will see two-way variable flows created by many smaller DERs connected to the distribution system or behind the customer meter. Safety and customer reliability issues will

Figure 3: Grid of the Future



increase in both frequency and magnitude unless system operators have the enhanced capabilities of a modern grid.

"The grid of the future will allow DSOs to take a proactive approach to identifying and resolving operational issues."

The grid of the future will allow DSOs to take a proactive approach to identifying and resolving operational issues as they arise. There will be more communications and automated equipment along the network that would allow the system to recognize a fault and reroute energy to another circuit, while accounting for the impacts of and on the DERs connected to the circuit.[viii]

Developing these operational capabilities requires expansion of fiber optic and field area networks for real-time data collection; automated sensors and devices to capture data and to control grid devices in response to real-time disturbances; and management systems to operate the distributed grid and markets (Figure 3).[ix]

With the right operational standards in place, DSOs could leverage DERs—bringing additional flexibility to the grid. For example, an electric vehicle charging station could reduce its power requirements to accommodate an overloaded system. The customer would voluntarily participate, receive compensation for the reduction in overall load, and charge their vehicle later at a lower cost. With the right technologies in the right places, the grid could optimize and manage the charging station's power consumption to benefit the customer as well as the grid.

Grid modernization and reinforcement, along with a capable DSO, are essential to enabling much greater distributed resource adoption and unlocking value, while enhancing reliability and resiliency for all customers.

2. Access to new markets—essential to expanding distributed energy choices for customers

Distributed energy resources, when connected to a modernized electric grid, may provide valuable services that extend their worth beyond their owners' specific uses. By monetizing these additional services, DER providers can create innovative new applications that expand the breadth of choices available to customers. Distribution System Operators will become more important in balancing the needs of customers, the grid, and other markets to realize the full potential of DERs. The DSO will offer greater visibility and performance certainty for these resources.

Grid opportunities for distributed energy resources

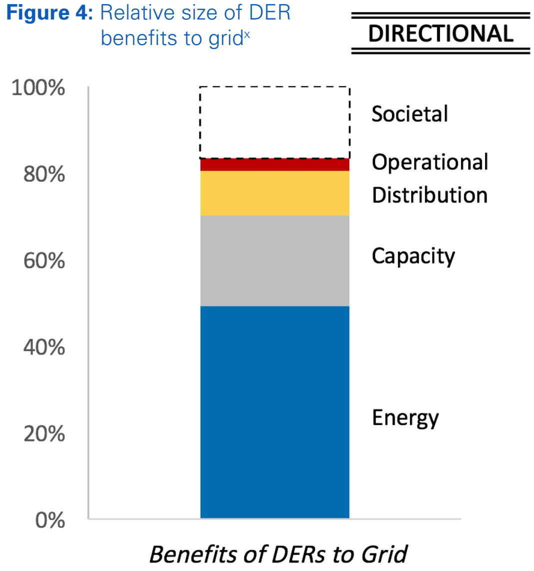
DERs can provide benefits to different elements of the power system (Figure 4):

- **At the wholesale energy and generation level**, DERs can provide energy and other services to existing wholesale markets that lower costs. With sufficient penetration, they might also defer the need for additional central generation, reducing carbon emissions.
- In terms of the **transmission system**, greater penetration of DERs in the right areas could mitigate load growth and affect resource mixes enough to alter the need for transmission solutions.
- At the **distribution level**, as DER performance is proven and costs decline, DERs can begin to provide services that are similar (or complementary) to traditional grid equipment.
- Controllable DERs, properly enabled, support the grid's ability to **integrate renewable energy sources and other distributed technologies** that are critical to supporting a lower carbon energy future.

Markets that unlock grid benefits

Today, retail DER customers don't have simple ways to participate in wholesale power markets, nor receive compensation for services to the local power grid. While in the early years, the primary focus of DSOs will be to ensure reliability as more DERs are introduced, they will also be key in facilitating distributed resource and aggregator participation in existing power markets, and in identifying opportunities for these resources to perform distribution functions.

Figure 4: Relative size of DER benefits to grid[x]



Wholesale energy and capacity markets represent the largest market opportunity to most DER owners. Currently, wholesale market rules place restrictions on the minimum size and performance characteristics of DERs that can participate.[xi] As rules change to allow greater DER participation, DSOs will be able to aggregate customer DERs or coordinate with third party aggregators to optimize DER usage between wholesale market products, distribution grid needs, and individual customer preferences. DSOs would play a critical role ensuring that directions from wholesale and distribution operators do not conflict and put reliability at risk.

> *"DSOs will help customers participate in markets, which can be difficult to navigate."*

In addition to this operational role, DSOs will help customers participate in these markets, which can be difficult to navigate. For example, DSOs could offer products that provide price certainty to individual DER owners. They might also administer local demand response programs or battery storage to shift load in specific grid locations, as opposed to broad, service territory-wide demand response programs limited only to emergencies.

Distribution services and the potential for DERs to provide benefits to the distribution grid are beginning to be explored.[xii] On average, the potential benefits of DERs to the distribution grid are smaller than the benefits from their contribution to wholesale energy markets. However, in specific locations the benefits could be substantial and a meaningful revenue stream for new DERs (Figure 5). One potential application is using portfolios of DERs to defer distribution load growth projects. As part of its role in system planning, the DSO would identify traditional wires projects that could be

Figure 5: Impact of DSO coordination of DERs on benefits to grid

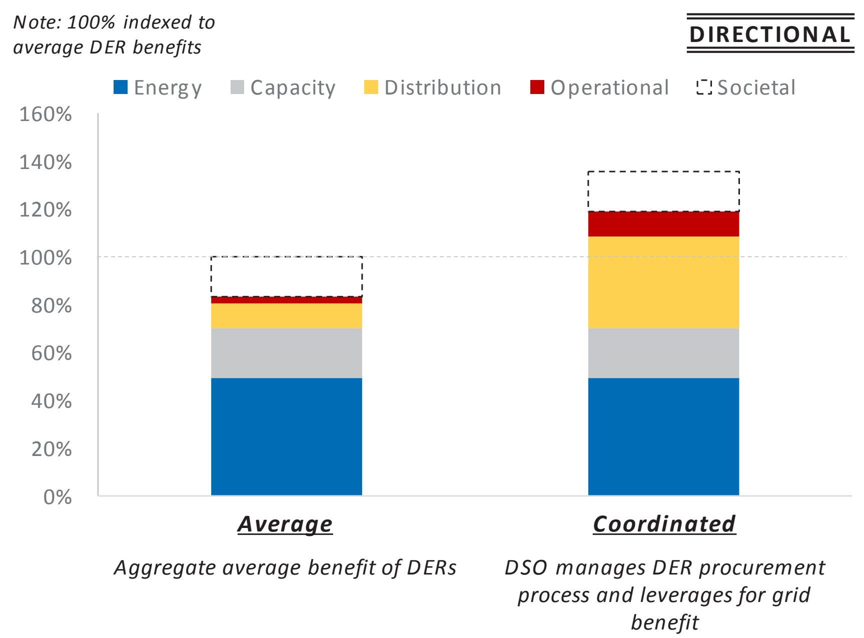
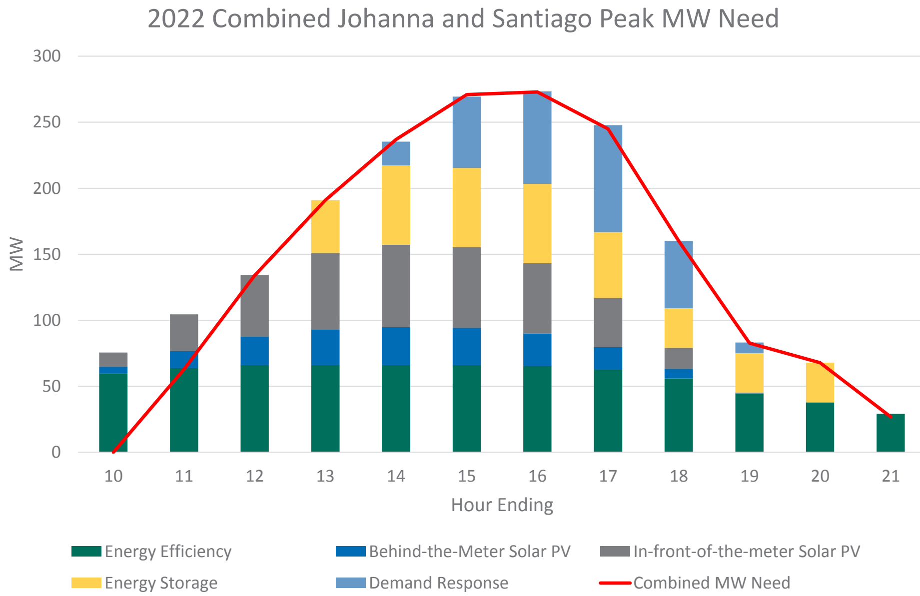


Figure 6: Sample DER Portfolio[xiii]



A mix of DERs sought to fill local needs on circuits out of Johanna and Santiago substations in Orange County, CA.

deferred, and contract for portfolios of DERs that result in the greatest net benefit for customers. Individual DERs alone are unlikely to defer system upgrades. Capital upgrades could employ large portfolios of DERs to replace them and still meet reliability criteria (Figure 6). System planners need visibility and certainty in the grid solution. DERs have to prove they will be available, dependable, and durable—accessible when required by the grid, performing the specified function, with an understandable and proven asset life.

> ***"DERs have to prove they will be available, dependable, and durable, with an understandable and proven asset life."***

There are other potential benefits that DERs could provide—voltage support, intermittent load integration, etc.—that require testing to prove and new market mechanisms for DERs to monetize the benefits. With access to this distribution platform, third parties will undoubtedly create new ways to benefit from DERs. Collectively, these new markets create alternate revenue mechanisms for DERs.

Putting market mechanisms to work

The performance of large-scale DER portfolios will offer key insights on market designs. Among the observations from the initial years: what customers want; what incentives they respond to; the performance of DER portfolios under actual operating conditions; and what third-party business offerings will be most effective and efficient.

Markets for DER participation will mature as DSOs and DER project developers gain experience in structuring transactions and incorporate new ways to make grid planning and market design more efficient. Customers and developers will grow comfortable with new markets and DERs will establish longer track records performing new grid services. DSOs will create (or sunset) new market products as grid needs, DER technologies, and consumer preferences evolve.

In general, Distribution System Operators will work with regulators, bulk system operators, DER providers, and customers to enable markets for DERs in three ways:

- Align compensation with benefit: DSOs will create competitive markets that compensate DERs for the services they provide to the grid.
- Provide visibility and access: DSOs will identify the specific needs of the electric grid and connect DERs to the markets that address those needs.
- Enable bundling of services: DSOs will ensure that the distribution grid operates reliably and optimizes the benefits of DERs as they provide services to wholesale, distribution, and other markets.

3. Balanced program and rate design—essential to ensuring fair energy access for all

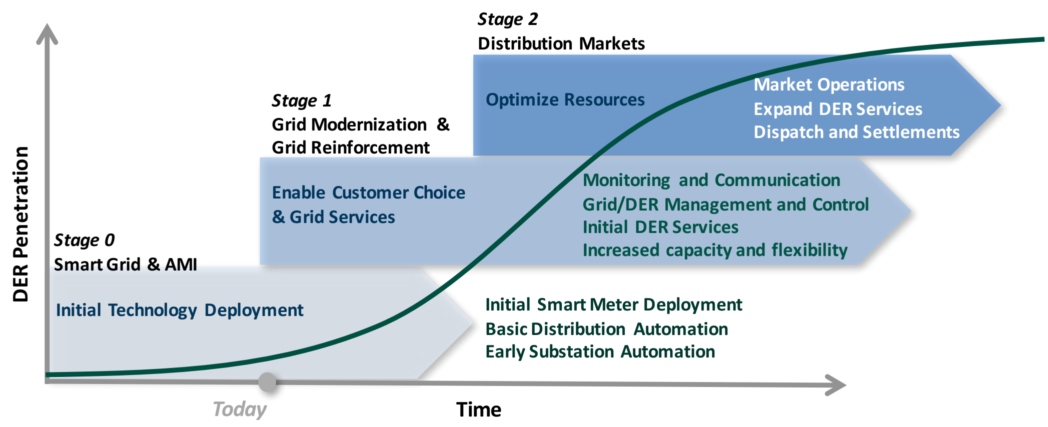
Benefits to the grid can vary significantly from location to location, but current policy tools, such as net energy metering and feed-in tariffs, do not capture these time- and location-related contributions. Regulators need to evaluate rate structures and program to incentivize DER adoption and performance consistent with carbon reduction and other policy goals. This includes assessing the potential for substantial cost shifting among customers.

The principle of location-based pricing at the distribution level should apply broadly to DERs across the system. At its simplest, a transparent payment mechanism could clearly identify the wholesale, distribution, and societal value of energy injected into a specific part of the grid. The DSO could update these mechanisms on a regular basis to reflect the economic fundamentals of the system and the experience of competitive markets, so that compensation reflects local system needs and market values. A gradual transition plan from current net energy metering programs to location- and market-based pricing for DERs must reflect environmental policy objectives, not disrupt customers' access to technologies, and maintain equitable cost allocation among all customers.

"A gradual transition to location- and market-based pricing for DERs must reflect environmental policy objectives, not disrupt customers' access to technologies, and maintain equitable cost allocation."

Ultimately, all customers will benefit when DER compensation aligns with actual benefits and costs to the grid. However, this requires not only locational pricing of DER exports to the grid, but also rate design changes to ensure that all customers pay for and receive the benefit of the services they provide and consume. Today, retail rates are largely volumetric and do not reflect the fixed costs of the grid.[xiv] Customer rates must evolve so that

Figure 7: Potential development of markets over time[XV]



Ramping up system upgrades and modernization is necessary today to enable future benefits

all customers of the grid make an equitable contribution to maintaining it, while not disadvantaging existing customers who presently rely on DERs.

"Ultimately, all customers will benefit when DER compensation aligns with actual benefits and costs to the grid."

In support of choice and clean energy policies, utilities could identify grid services opportunities and run targeted DER programs in underserved communities, including disadvantaged communities. Whether customers produce their own energy or purchase it from the power company or another retail provider, the distribution grid provides the essential connectivity to make everything work.

These changes—markets and programs that compensate DERs for the benefits they provide and rates that reflect the fixed costs of the grid—are essential to ensuring all customers receive affordable power and access to the grid as DERs become a more prominent part of a low-carbon, clean-energy future.

4. The path forward

Today's electric power industry is in the midst of profound transformation. One of the biggest challenges is unlocking the tremendous potential that technologies such as rooftop solar, on-site energy storage, electric vehicles, and energy management systems can provide to the local power grid while reducing carbon emissions. Enabling and encouraging DERs will facilitate greater customer choice—while also helping achieve clean energy policies and facilitating the growth of new markets for energy products and services. This transition will likely take more than a decade, which is why it must start now (Figure 7).

The early stages of this evolution will involve three key efforts, all of which will require a partnership among electric power companies, customers, technology providers, and regulators:

Grid modernization and reinforcement. Foundational capabilities like advanced distribution automation should move forward quickly to support increased connection of distributed resources. These technologies, along with proactive upgrades, will support rapid DER expansion so that the pace of adoption does not outgrow the capabilities of the grid.

DER performance validation. Before DSOs can use distributed resources for grid services and other market applications, their capabilities must be tested and proven available, dependable, and durable. The reliability of the grid depends on it.

DER market design and development. Unlocking additional benefits of DERs will require piloting and testing competitive solicitations, guidelines for comparing traditional investments with distributed alternatives, and payment structures for third-party projects.
In recent years, DER developers have dramatically reduced costs, improved performance, and expanded the choices available to customers. As these next steps unfold, the benefits of distributed resources to the grid, environment, and local economies will emerge. In order to realize all of their potential benefits, they will rely heavily on the local power distribution grid.
A modernized power system will place the customer at the center and transform utilities into facilitators of customer choice, thereby unlocking the environmental and customer benefits of distributed resources and maintaining the integrity, safety, and reliability of the power grid upon which everything depends.

“Enabling DERs will facilitate greater customer choice—while also helping achieve clean energy policies and facilitating the growth of new markets.”

More information on grid modernization at SCE and electronic copies of this white paper are available at:
Edison.com/TransformingtheGrid

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