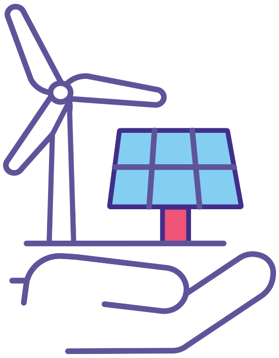

Unlocking Consumer DER Potential

Consumer-Centric Approaches for Grid Services

REACHING CARBON NEUTRALITY WILL REQUIRE significant increases in electrification and clean energy resources when compared to historical levels. This creates an opportunity for consumers and their distributed energy resources (DERs) both to play a significant role in achieving and to benefit from a 100% clean energy future. DERs are defined here as clean distributed generation, energy storage, energy efficiency, responsive demand, and electric vehicles (EVs). This article examines how this opportunity may be realized through a more customer-centric approach that also requires enabling industry and grid transformation.

Australia and California help illuminate the promise and the potential of a high-DER future. Recent modeling for Transgrid's "Energy Vision," Australia's largest electricity transmission business, was done by the Commonwealth Scientific and Industrial Research Organization, ClimateWorks Australia, and The Brattle Group. They compared six potential scenarios on emissions outcomes, total system costs, and average bills. In their Prosumer Power scenario, they wrote, "consumer choices and technology advancement

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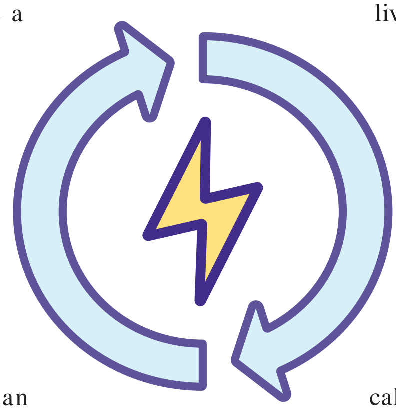
drive a very high penetration of well-coordinated distributed energy resources into the energy system."

This scenario achieves zero emissions by 2050 with the lowest average annual residential costs. This is inclusive of electricity bills and the costs of consumer investment in solar generation and energy storage. Similarly, the Southern California Edison (SCE) "Pathway 2045" white paper found the total cost of energy for the average consumer is expected to be reduced by 30% when considering the costs of fuel, the increase in load growth, and the investments required.

Realizing this potential with DERs, largely involving consumers' resources, requires a step change in consumer engagement and technical capabilities related to grid planning and operations. The Pacific Energy Institute's "A Gambit for Grid 2035" white paper described this as a structural transformation that is occurring to a cleaner and more distributed energy future (Figure 1). Global decarbonization policies often include a substantial contribution from DERs and beneficial electrification that, combined with grid modernization, can enable a higher level of overall system performance in terms of reducing societal greenhouse gases and increasing economic efficiency for consumers.



The first of the two S curves (in blue) in Figure 1 shows the current path of the industry. This represents the dominant paradigm of incremental adaptation that the industry has successfully used for many decades, but the effectiveness of this model is coming to an end. The second S curve (in green) represents a future industry structure and grid that has evolved to become more sophisticated regarding consumer engagement and the capabilities to integrate and utilize very high levels of DERs. As the Pacific Energy Institute white paper noted:

> We are nearing the tipping point in the proliferation of large scale and distributed renewables and storage, in increasing customer participation in the marketplace, and in the growth of transportation electrification within this decade. The industry has already entered this transitional period involving structural transformation. The industry has "crossed the Rubicon."

As such, the emerging more distributed system, with significant resources connected at both the transmission and distribution side, creates changes for system planning, grid architecture, and the business ecosystem. Also, consideration of a new energy compact with consumers to engage as grid partners is being explored given the interest to leverage consumers' substantial investments in DERs to enable the power system to operate efficiently and reliably. This is in recognition of a changing role from simply consumers of grid services to also becoming producers of energy and grid services.

Global consumer research shows that consumers are willing to play their part in this transition to a clean energy future. But what will be required of them in such a power system given the exponential trajectory of technological innovation? Will the electric power industry still employ methods that require consumers to change their lives to accommodate the power system, as is the case through time-of-use (TOU) rates or traditional heating and cooling direct load control schemes? Or will the emerging advances in building and home automation (battery energy storage, for example) allow for less-intrusive energy reductions, during periods when consumers need to use electricity, that can also be operationally more dependable? Expectations of consumers and their resources as a critical part of a clean energy future and those reciprocal expectations of the industry are central questions that must be addressed.

DER Adoption Trajectory

Realizing this potential of a high-DER future inherently depends on the ability and willingness of consumers in aggregate to make investments that impact their electricity use and to switch from using fossil fuels in their homes, vehicles, and businesses. Rather than continuing to frame these choices and policy responses in the abstract, understanding the sociotechnical challenges and consequences for a diverse range of consumers is necessary. This has become critically important to address now as many parts of the world are on a trajectory that follows the experience of Australia and California.

Today, Australia has the highest rate of installed solar capacity per capita in the world with 3 million homes having an aggregate of 15 GW of solar systems on their rooftops. This is the majority of the 23 GW of solar installed through 2021 based on Australian PV Institute data (Figure 2). Clean resources are expected to account for 100% of generation by 2050 with a distributed solar capacity of 80 GW and distributed storage of 70 GW (from 1 GW today).

Over the past decade, California has also seen rooftop solar photovoltaic (PV) capacity grow exponentially to more than 10 GW, based on California interconnection data (Figure 3),

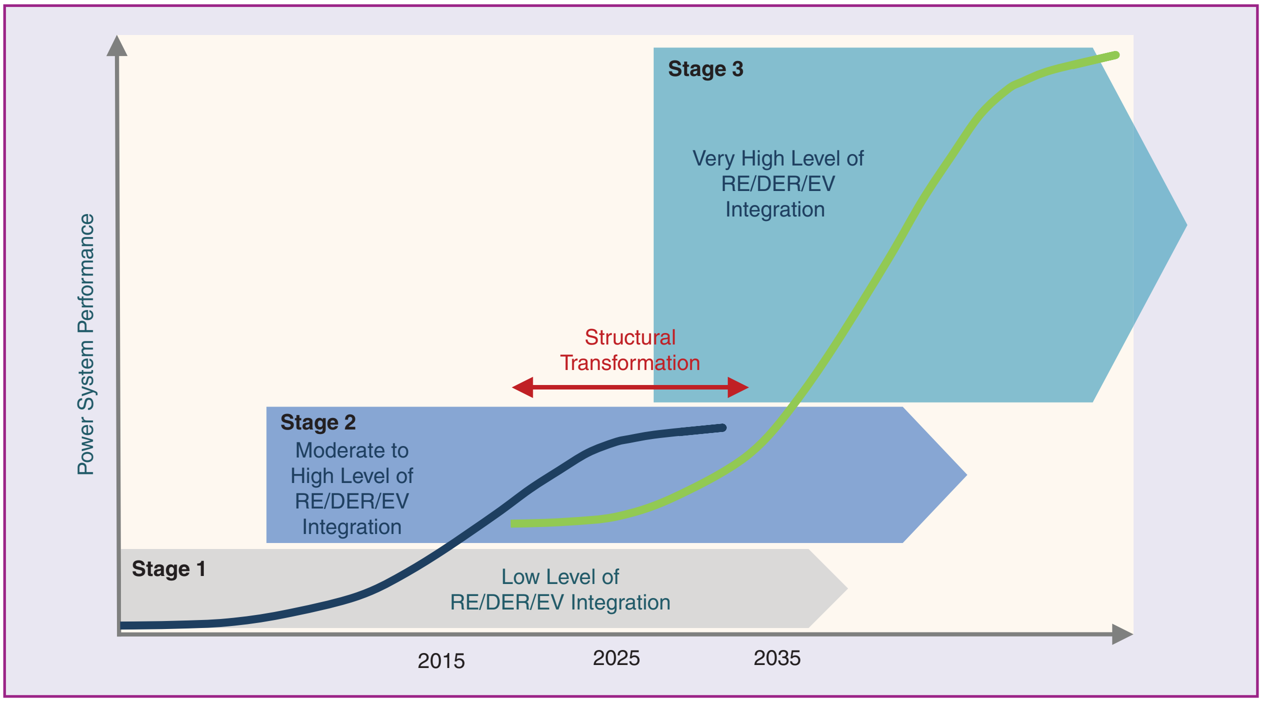


figure 1. Electric power industry structural evolution. (Courtesy of P. De Martini)

and the trend is expected to continue. SCE's forecast to achieve California's greenhouse gas emission reduction goals for 2045 indicates that 100% of retail sales in the state will need to come from carbon-free resources. This includes 80 GW of utility-scale clean generation and 30 GW of new utility-scale energy storage to integrate the variable renewables. Additionally, 30 GW of clean generation and 10 GW of storage will come from DERs. These proportions of DERs to utility-scale resources are very similar to Australia's expectations.

With electrification in California, all that clean energy will be needed to fuel an estimated 60% increase in electricity sales and a 40% increase in peak load. Translated to consumers in SCE's service area, this means that as many as 75% of vehicles will need to be electric, with solar PV growing from 8 to 30% of households (1.6 million households), energy efficiency savings growing from 35 to 52 TWh, and battery energy storage increasing from approximately 12,000 to 400,000 households by 2045.

The growth of variable and inverter-based resources and EV charging is making power systems more dynamic. The European Network of Transmission System Operators for Electricity (ENTSO-E) paper, "Options for the Design of European Electricity Markets in 2030," notes, "flexibility needs increase with progress toward 2050 climate neutrality and 2030 greenhouse gas reductions targets of 55% due to increases in variability and uncertainty."

Power systems are becoming less predictable in daily operations. Historically, load could be predetermined with a high degree of probability based on weather, and generation production could be predetermined based on power plant availability. However, the historical net load patterns of 10 years ago do not apply today and are not expected to be the

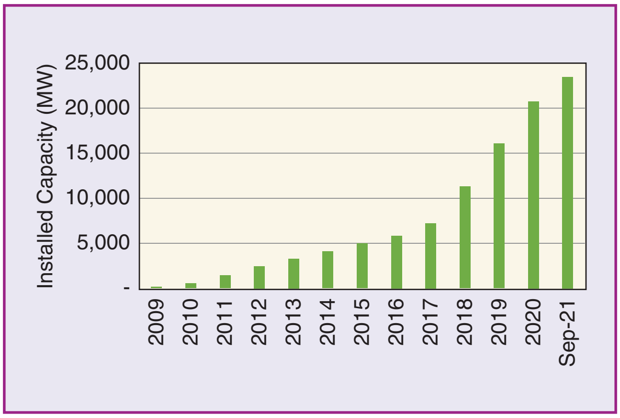


figure 2. The total solar PV installed capacity in Australia.

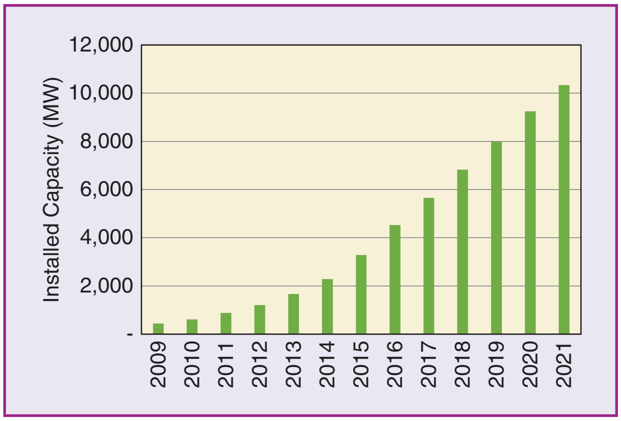


figure 3. The rooftop solar PV installed capacity in California.

same in another 10 years. This is due to increases in distributed renewable generation, consumer-sited storage, and electrification of transportation combined with ever-changing work environments (e.g., remote work) and lifestyles that will likely continue to evolve operational patterns, including a potential increase in variability.

An increase in variability has the effect of placing a greater need on flexible resources, including flexible DERs, that can address the shorter response times needed for real-time grid operations. That is, to address the increasing variability of energy production and consumption, there will be an increasing need for grid services that are in continuous operation with response times below 5 min, and for several services, below 1 s. Individual and aggregated DERs will also need to provide firm services in that grid operators need greater certainty on availability and actual performance in real time (Figure 4).

This evolution is identified in ENTSO-E's recent "Assessment of Future Flexibility Needs," which stated:

> Flexibility is thus increasingly needed for maintaining the balance of demand and production on all time horizons in the face of increasing scale and frequency of fluctuations… It is also increasingly needed for balancing forecast errors on intraday and balancing markets for transfer capacities, voltage, and power quality.

Flexible Consumer Resource Management

In a clean and more distributed energy system, consumers could be the heroes—responsive and responsible managers of their energy usage and energy resources to benefit themselves and others. However, understanding consumers' values and expectations more fully is necessary if DER coordination is to become a critical success factor in achieving decarbonization. Consumer expectations include:

1) affordability—lower energy bills for all consumers
2) consumer choice and control over how they use energy and opportunities to benefit from their DER investments
3) a trusted, resilient energy system designed for all consumers.

A current issue for regions with high DER adoption is the mismatch between when most electricity is generated by renewable generation and when most electricity is needed by households and businesses. In response, current policy strategies include efforts to reshape consumer demand to align with generation production. This is referred to as *flexible demand management*. Scaling may be difficult given the dual challenges of consumer willingness to participate and the increased need for grid services with very short operational timing. Understanding and addressing consumer needs may be vital to attracting consumer participation at the level needed to achieve 100% clean energy.

Traditionally, demand management involved TOU rates structured in hourly increments and direct load control programs (i.e., utility and aggregator). The programs involve human decisions, such as a grid operator identifying an issue and then requesting a program administrator and/or aggregators to provide a specific response. These aggregators, in turn, initiate a control action based on DER availability and program and/or contractual parameters. The time involved to identify an operational need and engage the DER response may take several minutes. Also, public service calls for load reduction have been used to respond to occasional periodic supply shortages. These calls can take well over an hour from need identification to meaningful consumer response.

As smart home and building automation technologies have become more sophisticated, the opportunities for more automated methods of managing load have become more prevalent. These "set-and-forget" programs are often designed to minimize consumer impacts by operating in the background. Additionally, these programs may be linked to transactive energy or other dynamic prices to load device initiatives (e.g., smart thermostats) that use prices as the trigger for a demand reduction. This has been employed in cases where consumer premise battery storage (i.e., stationary and/or EV) is the controllable device. These methods can operate more quickly than some earlier programs, but their contributions to meeting the system operation performance requirements need study. As a transactive price formation process of bid reconciliation may take 5 min or more, the speed of reaction may only partially address the needs of a more dynamic power system.

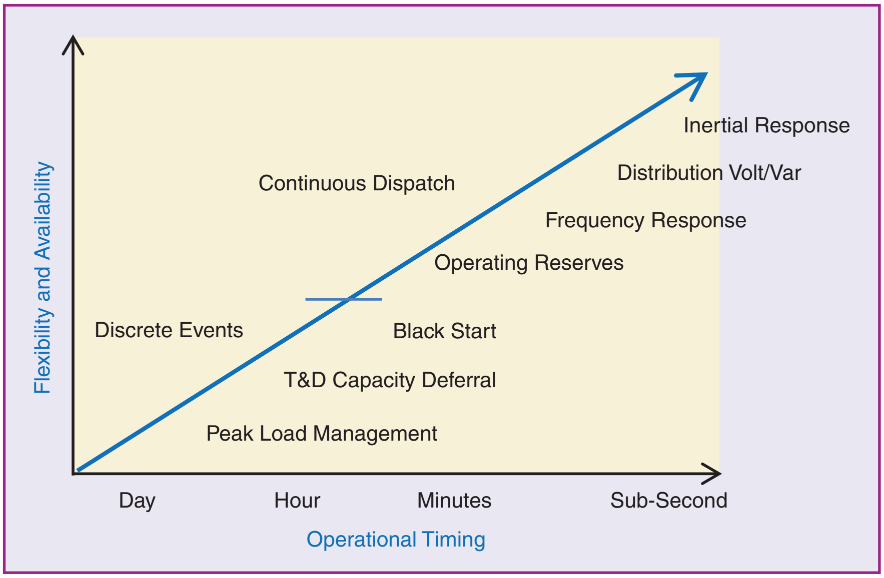


figure 4. Potential flexible DER applications. (Courtesy of P. De Martini)

Figure 5 illustrates the current types of operational control solutions employed and the potential for autonomous solutions, imperceptible to consumers, that are beginning to emerge. The current flexible load management control archetypes (shown in blue) each have varying impacts on consumers' ability to use electricity in their lives or business if not enabled by advanced home and building automation. Calls to reduce energy in the evening can be disruptive to consumers. For example, California's current Power Down initiative requests people to reduce electric power consumption from 4 to 9 p.m. every day all year. TOU rates also involve a high level of consumer engagement and action and potential disruption to a consumer.

Traditional direct load control programs also have a significant potential disruptive impact on consumers, as seen in the fatigue rates after a series of load reduction events. To reduce fatigue rates and ensure that load flexibility can be repeatedly utilized, a more sophisticated level of operation can be employed—automated direct control and autonomous operation (shown in green).

Automatic direct control involves a generation management system or distributed resource management system directly controlling resources based on changes in power system operating conditions. Automatic generation control dispatch (4-s intervals) of distributed stationary battery storage, bus fleet batteries, or building automation systems is an example of automated direct control.

Autonomous control involves a device or system responding independently to sensed changes in grid operating conditions, such as changes in secondary frequency or voltage in subseconds. An example is an advanced inverter responding to changes in distribution line voltage using the autonomous functionality incorporated into its design.

These systems use advanced DER technologies, controls, measurement, and communications capabilities to enable automated home and building operations and control. "They can enhance occupants' comfort and productivity while using less energy than a conventional building," as noted in a 2017 American Council for an Energy-Efficient Economy report, "Smart Buildings: Using Smart Technology to Save Energy in Existing Buildings." These approaches are designed to reduce energy usage in a manner that is imperceptible to consumers. This level of more advanced automation will also require a higher level of consumer trust in the electric power industry, including DER aggregators and other services providers.

Consumer participation is not likely to dramatically increase until the methods employed for flexible resource management align with consumers' lives or businesses. This alignment would involve a more consumer-empathetic approach—understanding consumers' motivations and values, including self-reliance, independence, and financial reward—in developing grid partnership programs that leverage consumers' DER capabilities.

All this suggests an opportunity to consider that a new paradigm for consumer engagement is needed, including: 1) a consumer cocreation approach that encourages consumer participation in the problem-solving and program design process to produce a mutually valued outcome and 2) pursuing more imperceptible automated solutions to utilize consumer energy and demand resources. An important dimension is building a social license between consumers and grid operators for this new paradigm.

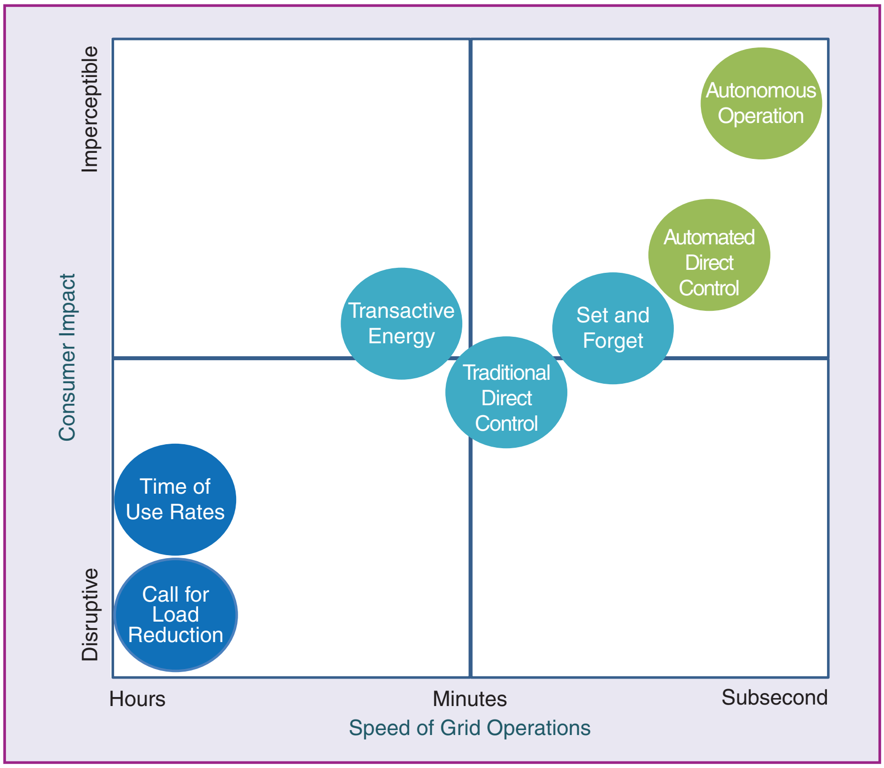


figure 5. Flexible resource management solutions. (Source: P. De Martini and P. Cook.)

An example framework is the International Energy Agency's "Social Licence to Automate." Such a social license provides consumers the control and the trust that they are not undertaking undue risk to become active partners in the grid. Otherwise, experience shows that they will not participate at the scale needed. This paradigm shift will not happen quickly. The legacy programs of today will take time to evolve, but this shift needs to occur if the level of participation is to be reached.

Planning a Hybrid Grid

Planning in this high-DER, the consumer-centric environment should consider a high degree of coordination between consumer investment in DERs and efficient investment in utility-scale resources, transmission, and distribution to achieve affordability objectives. In this regard, the future grid will not only need to respond to the challenges of increasing electrification of transport and heating but also provide opportunities for more local generation and energy storage. These resources may come from microgrids and community or shared solar and storage connected at the distribution level. This future grid would need to be a modern, flexible, and resilient energy system based on abundant, low-cost clean energy to support rising living standards and greater social inclusion.

Traditional planning methods largely employ simplistic assumptions about motivating consumer choices. There are challenges to address modeling consumer behavior, including: 1) understanding consumer decision making in the adoption and use of DERs, including EVs and 2) understanding what level of financial risk and opportunity cost consumers are willing to undertake to provide grid services.

System planning for the future grid may consider these consumer issues as part of the broader challenges facing the grid today as the transition to grid-enabled decarbonization accelerates. Trends that also may be considered include the following.

- ✔ *Consumer technologies will continue to advance and expand*: The increased use of electricity with higher density due to electrification will need to be served and will significantly increase reliance and expectation on electricity availability in the future.
- ✔ *Clean energy transition will expand inverter-based resources*: Increasing levels of inverter-based resources, such as wind, solar, and battery resources, will create operational challenges for a grid that was designed around synchronous machines.
- ✔ *Climate-driven impacts will worsen*: Vulnerabilities created by extreme temperatures, drought, sea-level rise, and wildfires will increasingly impact reliability and resiliency and will require adaptation strategies.
- ✔ *Cyberphysical threats will continue to increase*: As technologies and deployment proliferate, external threats to the grid and consumer DERs will need to be addressed (including supply chain vulnerabilities).

Another challenge is how to make a successful transition from today's centralized grid to a more distributed clean energy grid given the high degree of uncertainty facing this industry and the relatively short time to address this transition. Techniques such as strategic foresight can augment traditional planning analyses to identify potential strategies. Strategic foresight would involve identifying emerging patterns of a more distributed power system around the world that illustrate possible future grid evolutionary pathways. Insights from how these areas address emergent issues could help determine the key attributes of successful consumer engagement and future grid operational strategies.

These "postcards" from the future can be useful to develop scenarios regarding the scale, scope, and pace of change needed to achieve a 100% clean energy future grid. New scenario planning tools and probabilistic methods will enable better decision making given the high degree of uncertainty of the pathways to a 100% clean energy future.

As the Australian Energy Market Operator recently described in its National Electricity Market Engineering Framework, "the path to the power system of the future will need to be carefully engineered and intentionally designed with both today's power system and the ultimate end state in mind." In the context of the second S curve in Figure 1, the Australian Energy Market Operator notes the following

"…It is critical that designing a step change in power system capability starts today, due to:

- ✔ The extent of work and collaboration required across many areas, including technical engineering, planning, and regulatory reform.
- ✔ The pace of change underway and the asymmetric risk to consumers of disorderly, constrained and inefficient transition.
- ✔ The risks if timely action is not taken and system operators do not have the tools to securely and reliably manage new operational conditions as they emerge."

Grid Architecture

A cleaner, more distributed energy future requires a thoughtful grid architecture that enables highly interconnected resources across the consumer, distribution, and transmission tiers to support balancing supply and demand, ensuring power quality, responding quickly to changing conditions, and improving the overall reliability and resilience for all consumers.

An architectural approach can provide better ways to organize capabilities in various layers to provide a scalable structure and thus manage complexity. This approach includes foundational layers providing broad situational awareness from a ubiquitous sensors network layer and processing data and information across a high-speed communications network layer managed by the next generation of grid management systems. These core technologies will enable applications like state estimation and anomaly detection. They will allow the automated adjustment of grid configurations and protection settings in response to rapidly changing conditions.

A more comprehensive grid architecture that brings these technologies together will also need to meet unique consumer needs. For example, heavily populated areas or dense load pockets with significant penetration of electrification and DERs may require situational capabilities such as high-throughput designs. Also, alternative grid architectures may be applied, such as remote areas served by microgrids to ensure resiliency.

The integration and coordination aspects of grid architecture are reflected in the grid codes for large-scale energy resources and DERs. These essential codes (referred to as *interconnection standards* in the United States) must reflect the changing system requirements. The expanding use of DERs as grid resources requires consideration of how best to leverage IEEE 1547–2018 (a DER interconnection standard) capabilities, particularly the multiple autonomous capabilities.

If distributed generation and storage integration and coordination are properly architected, they could contribute to power system resilience. For example, distributed generation and storage could improve the survivability of the power system by enabling multiuser microgrids within a distribution circuit or at a substation during and following extreme disturbances. Additionally, they could support the restoration of the overall system by providing a black-start capability through a bottom-up approach, facilitating the recovery phase. These use cases would require grid-forming inverters. Today's DER inverters are typically grid following and incapable of providing these resilience functions. This illustrates the need to standardize grid-forming inverter capabilities. When defining grid code requirements, looking ahead to anticipate future changes in the power system is important so that the requirements are not outdated after a few years.

Additional technical challenges must be addressed. Advanced control schemes will be needed to enable DERs to contribute to power system resilience. In the case of black-start and multiuser microgrids, these schemes must be capable of fine control of DERs so that they can manage imbalances between available power from energy-exporting DERs and consumer demand. As these control schemes will rely on the exchange of data between numerous subsystems and devices, their cybersecurity will have to be properly managed to avoid vulnerabilities toward cyberattacks that otherwise will compromise resilience.

DERs could play an important role in the mitigation of these emerging threats. Additional grid capabilities would be needed to enable and empower the active participation of consumer-owned DERs in providing grid services and minimizing adverse impacts on reliability and power quality (Figure 6). Incorporating customer DERs would require resource coordination across transmission–distribution–consumer interfaces to ensure the overall balance of supply and demand.

Reliable system operation would be highly dependent upon proactively addressing grid code requirements within an overall grid architecture. Also, it would be necessary to reevaluate operations and protection to consider enhanced defenses against cybersecurity threats as the grid becomes more interconnected. These profound advances and expansion in distributed generation and storage, in the context of rising electrification and greater reliance on electricity, would pose additional complexities in the design and operation of the electric grid.

Industry Structural Transition

To accelerate and achieve ambitious goals such as 100% clean energy, the electric power industry may need a significant paradigm shift to harness modern-day capabilities and foster a culture of innovation. After 20 years of business disruptions in most industry sectors, the electric power industry remains largely bound to traditional methods and technologies. This dependence may need to change dramatically as the digitalization of the power system from consumer to wholesale markets becomes a reality. Such a change would require a fast tech-level pace of industry innovation and system modifications to match the change in the transition to clean energy generation and necessary climate adaptation.

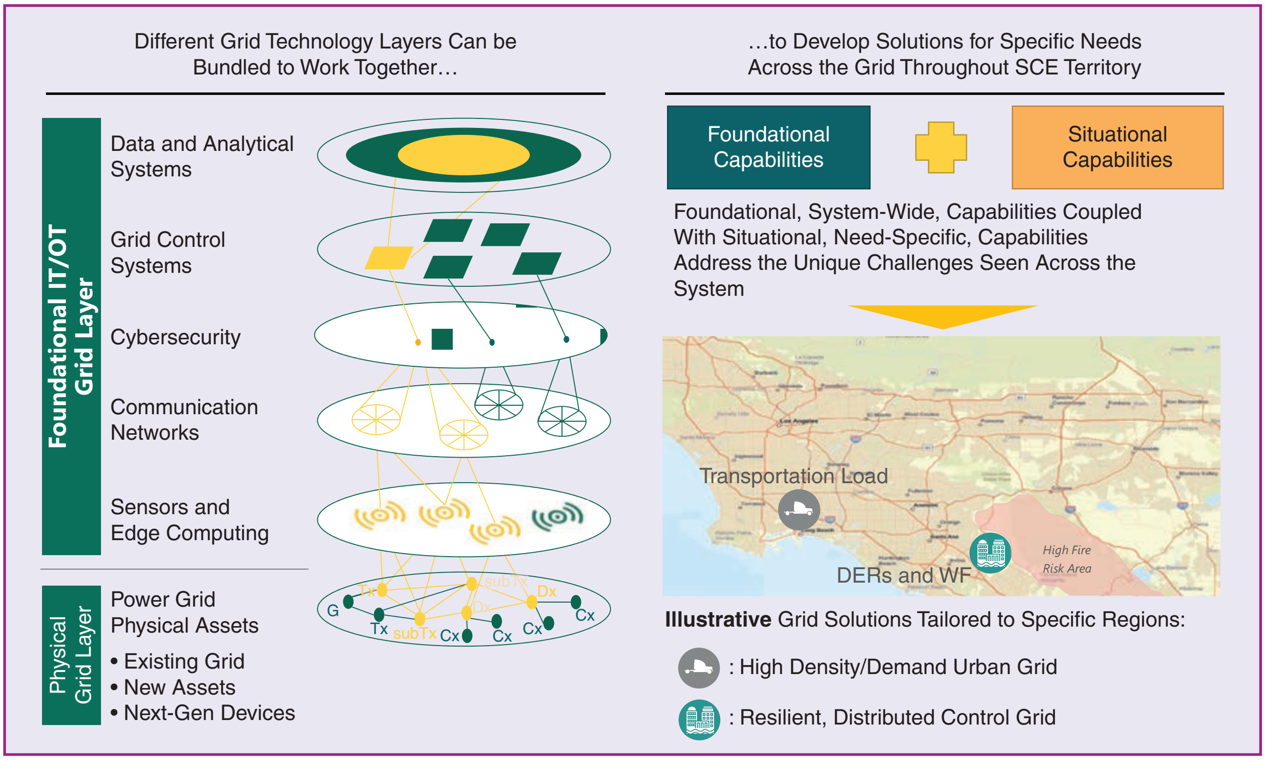


figure 6. The SCE grid architecture vision. (Source: SCE.)

That is, design the architecture of the power system and markets from a technology perspective as a "digital native" (those born in the Internet era) would. A specific example is adapting the concept of constraints that deconstrain, which fundamentally changed information technologies. This adaptation involves properly chosen constraints that can free upstream and downstream decisions. For information technology, this involved identifying the protocols among hardware, operating systems, and applications in simple terms. For a regulated industry, like electricity, it means selecting the minimal constraints that determine what a business entity can and cannot do regarding new products and services, technology adoption, business processes, and organization changes.

Today, all of these are currently constrained to various degrees in the current industry structures and regulations. While it is common to focus on what is not allowed, well-chosen constraints can enable new and abundant capabilities and functions that matter in enabling the transformative change of the electric power industry to address evolving consumer expectations for electricity services.

This shift in orientation occurred in the information and media industries, which previously viewed their respective services and products in uniquely different silos and ecosystems with related regulatory constraints. As consumer expectations changed and were enabled by technology and business innovations, the silo boundaries began to blur, and by the 2010s, these boundaries collapsed into a converged ecosystem more responsive to consumer demands. The closed industry sector–walled gardens evolved into cross-sector partnerships and a greater flow of information and access that enabled business innovation.

Similarly, the adoption of alternative energy supply and reliability services and capabilities has largely happened outside the traditional electricity ecosystem structure. However, each silo has had profound impacts on each other's business. The situation appears to be changing as businesses on either side of the meter begin to traverse that boundary to form new collaborative relationships to address consumer needs. Policymakers are recognizing the opportunity to allow for beneficial relationships among utilities and competitive services firms to offer consumers greater choice to achieve decarbonization goals.

Consumer Energy Compact

The 100% clean energy future portrayed in this article depends upon the consumer adoption of electrification and DERs, new individualized energy services giving consumers choice and control, and enabling consumers to be responsive and responsible managers of their energy usage and generation. This emergent behind-the-meter consumer activity is increasingly extending well into the grid side of the meter as opportunities to utilize DERs to provide power system services expand. Much work remains to be done to understand and reflect consumer values and changing expectations into industry policies, planning, and operations. As such, this transition raises several sociotechnological considerations, as described earlier, that suggest structural changes for the electric power industry.

Paramount is the need for all entities in the electric power industry to more completely understand consumers' needs and expectations toward a cleaner, more distributed future (Figure 7). Consumers who are willing and able to invest in generation, storage, or home energy management technologies are no longer passive users of electricity sourced only from the grid nor wholly dependent upon the grid for resilience.

Consumer equity implications are also increasingly under consideration. For example, grid infrastructure cost recovery may be different for households with and without rooftop solar and households with and without energy-efficient measures. Consider the case in Australia, where 3 million more homes may have rooftop solar installed by 2050, which would be around half of all homes nationally. To the extent that solar homes meet some of their own electricity needs, the largely fixed costs of the grid may have to be recovered to a greater extent from those without solar.

Governments and industry are also increasingly recognizing that the pathway to electrification will need to address the challenges in transitioning dual-fuel households to all-electric as well as the adoption of EVs. This is a large and complex undertaking. In Australia, for example, it will require fully electrifying more than 4 million households that currently use both gas and electricity. Transitioning these homes is expected to reduce emissions by 100 metric tons (18% of Australia's total emissions), according to the "Castles and Cars" technical paper released by Rewiring Australia (a group espousing positive climate and economic outcomes possible for Australia).

Energy Consumers Australia (a consumer advocate) undertook detailed research into consumer expectations in 2019. One of the strongest findings was that households and

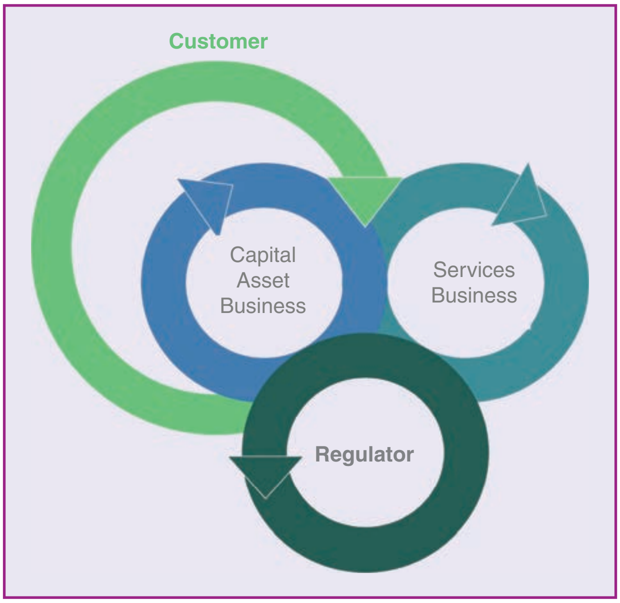


figure 7. The customer-empathetic electric power industry dynamic. (Source: Pacific Energy Institute.)

small businesses are willing to play their part in the transition to a clean energy future. However, they want to be assured that there will be reciprocity—that the institutions and industries that make up the power system will also play their part in enabling and empowering consumer choice and control. Consumers also expect that the future power system will be affordable and that it will be fair to people with the fewest resources and opportunities.

One aspect to unlock the potential of consumers to help achieve 100% clean energy may be building a new compact with households and small businesses responsible for investing and participating in that future. The Australian Council of Social Services (an advocate for disadvantaged people) and the Total Environment Centre (an environmental advocacy organization), with the support of Energy Consumers Australia, have proposed such a consumer energy compact that highlights the following key points raised in this article.

- ✔ *Make it consumer focused*: Design with and for consumers today and in the future. Ensure that everyone can access clean, affordable, dependable energy.
- ✔ *Deliver clean and healthy energy*: Transform the energy system to achieve net-zero emissions by enabling the environmentally sustainable production and use of energy. The transition to a clean energy system is a shared responsibility.
- ✔ *Make sure it works*: Ensure that consumers can depend on energy system resilience and efficiency across the supply chain, promoting efficient energy use and new technologies and services that benefit people and the environment.
- ✔ *Think long term and be flexible*: Focus on delivering the energy system needed in the future to improve the outcomes for consumers and communities. This system is flexible, innovative, responsive, and based on consumers' expectations.

This consumer energy compact is driving Australian industry leaders' decisions regarding this clean energy transition. This compact includes both consumer engagement and the grid architectural considerations on the use, production, and sharing of energy. Such a compact could be part of an integrated national plan that provides a clear vision for a high-DER future and the policies and programs to achieve it.

Conclusion

Given the scale of the task, a clean energy future requires a broad-based partnership between and across industry, government, the finance sector, and not-for-profit organizations to incentivize and invest in retrofitting homes with a particular focus on those in energy poverty. The transition to a clean energy future cannot leave anyone behind. Policymakers, market operators, and utilities are increasingly recognizing that consumer perspectives as dynamic producers and consumers of energy should be considered as a key part of a future power system that achieves 100% clean goals.

For Further Reading

"Energy Vision: A clean energy future for Australia," Transgrid, 2021. https://www.transgrid.com.au/media/x4mbdody/transgrid_energy_vision.pdf

"Pathway to 2045: Update to the clean power and electrification pathway," Southern California Edison, 2019. https://newsroom.edison.com/_gallery/get_file/?file_id=5dc0be0b2cfac24b300fe4ca&ir=1

"A gambit for grid 2035: A systemic look into the disruptive dynamics underway," Pacific Energy Inst., 2021. https://pacificenergyinstitute.org/wp-content/uploads/2021/08/A-Gambit-for-Grid-2035-final-version.pdf

"Options for the design of European Electricity Markets in 2030," ENTSO-E, Apr. 2021. https://eepublicdownloads.entsoe.eu/clean-documents/Publications/Market%20Committee%20publications/210331_Market_design%202030.pdf

"Overview of the New Energy Compact: Total environment centre and energy consumers Australia," Australian Council of Social Services, Consultation Draft 5.0, Nov. 2020. https://www.acoss.org.au/wp-content/uploads/2021/02/NEC_Consultation-Draft-V.5-04122020.pdf

S. Adams *et al*., "Social license to automate: Emerging approaches to demand side management," IEA User-Centred Energy Systems, Oct. 2021. https://userstcp.org/wp-content/uploads/2019/10/Social-License-to-Automate-October-2021.pdf

"Assessment of future flexibility needs," ENTSO-E, Oct. 2021. https://www.entsoe.eu/news/2021/12/02/assessment-of-future-flexibility-needs-in-practice-entso-e-report-and-position-paper/

"Smart buildings: Using smart technology to save energy in existing buildings," American Council for an Energy-Efficient Economy, Feb. 2017. https://www.aceee.org/research-report/a1701

"NEM engineering framework initial roadmap," Australian Energy Market Operator, Dec. 2021. https://aemo.com.au/-/media/files/initiatives/engineering-framework/2021/nem-engineering-framework-initial-roadmap.pdf?la=en

"Castles and cars," Rewiring Australia, Oct. 2021. https://global-uploads.webflow.com/612b0b172765f9c62c1c20c9/615a1e5c7bec5c70d6d3f346_Castles%20and%20Cars%20Rewiring%20Australia%20Technical%20Study.pdf

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