From Millions to Billions:

SCTE Standards Evolve the Smart Grid at Scale

A Technical Paper prepared for SCTE by

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1. Introduction

New global initiatives support the electrification of the planet, and the demands for power will continue to rise and stress the already-strained global electric power grid. Electric power directly affects costs for cable broadband, many industries and consumers, and is a root cause of soaring inflation. In response to increasing costs and power outages, federal and state legislatures and regulators, utilities, and energy managers are rapidly reorganizing energy mixes, focusing on the resiliency, sustainability and affordability of electricity generation, transmission, distribution, and storage.

Because utilities are increasingly dependent on the Internet to manage the delivery of electricity, cable broadband providers have a unique opportunity to provide innovative new services to the electric grid and commercial microgrids. These new services can save billions of dollars in fuels and other costs. In Texas, generation fuel savings of $1 billion dollars a year are possible by time-shifting demand for electricity which would also extend the life and carrying capacity of the end-to-end, generation-to-load power grid.

As societies depend more on non-carbon-based electricity and less on fossil fuels, new broadband standards create valuable opportunities to reduce unnecessary power generation, delivery costs, and outages. Two new standards by American National Standards Institute (ANSI) and the Society of Cable Telecommunications Engineers (SCTE) could ensure seamless integration of broadband-enabled electricity services by all types of users across the globe thereby allowing for rapid, efficient, and effective adoption in transportation, buildings, industry, and agriculture.

The two new standards leverage the decades of investment in broadband networks to manage and monitor the grid and enable its transformation more efficiently. The ANSI/SCTE 267 grid *management* standard improves the efficiency and capacity of generation, transmission, distribution, and storage of electricity by orchestrating electricity demand relative to optimized supply. The ability to continuously manage demand at scale is needed to mitigate the increasing grid operational challenges of distributed energy resources such as fixed and mobile batteries and other flexible electric loads, especially as dispatchable thermal generation is retired and replaced with variable renewable energy. In addition, the ANSI/SCTE 271 grid *monitoring* standard provides a quantum leap in detecting, predicting, and proactively addressing conditions relevant to distribution grid faults, safety, reliability, congestion, and the hosting of renewables and electric vehicles.

Broadband providers may partner with utilities to distribute ANSI/SCTE 267 signals to electricity consumers to optimize electrical load on the grid and may deploy ANSI/SCTE 271 sensors throughout the outside plant to provide utilities with extremely fine-grained telemetry on grid performance. These control and measurement tools can profoundly influence the reliability and affordability of power used by both cable companies themselves and their customers.

2. Why Evolve The Grid

To understand cable broadband's role in services and standards, we first examine the evolving grid. A confluence of factors creates unprecedented challenges in grid operations and business models. One factor is the rising costs of electricity in global markets. For example, at the time of drafting this paper, the Northeast U.S. wholesale prices are forecast to exceed $100 per megawatt hour (MWh) between June and August 2022, up from an average of about $50/MWh last summer. Figure 1 shows forecast increases in wholesale electricity prices across the U.S. from the Summer of 2021 to 2022.[1]

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[1] U.S. Energy Information Agency, Short-Term Energy Outlook (6/16/22), *EIA expects significant increases in wholesale electricity prices this summer.* https://www.eia.gov/todayinenergy/detail.php?id=52798

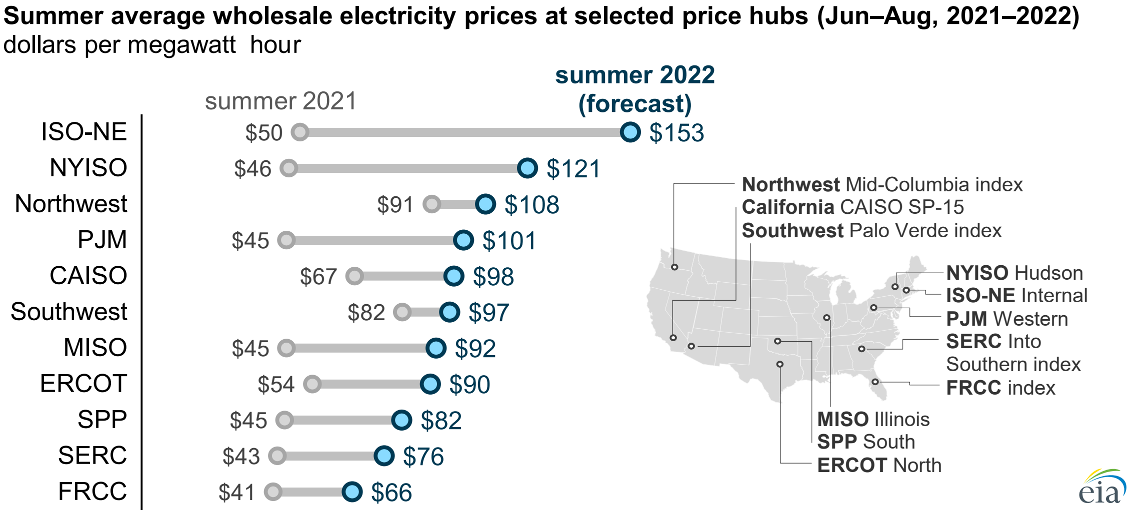

Figure 1 – U.S. Summer 2021-2022 Average Wholesale Electricty Prices.

While there are various reasons for rising wholesale electricity prices, the cost of generator fuel is a primary driver. Across the U.S., the price of natural gas delivered to electric generators is expected to average $8.81/Million British thermal units (MMBtu) this summer, up 125% from $3.93/MMBtu last summer.[2] Price increases in Europe and elsewhere are expected to be much higher.

In the past, when natural gas prices have risen, power providers with natural gas plants have substituted coal-fired generation. More recently however, many coal power plants are less likely to be used because of continued coal capacity retirements[3] and lower-than-average stocks at coal plants.[4] Other industry conditions that can contribute to higher wholesale electricity prices include fuel and water scarcities. For example, restricted contribution of hydropower this summer will likely lead the State of California to generate more electricity from natural gas and to import electricity from neighboring states.

Another factor creating unprecedented challenges in operating the grid is increased outages resulting from declining reliability of near end-of-life grid components, infrastructure frailty in severe storms, and lack of anticipated generation resources. Higher electricity demand coupled with potential supply reductions are raising concerns around the world. For example, the U.S. Midcontinent System Operator (MISO) has predicted outages this summer based on the anticipated shortfall of supply resources to meet normal and extreme demand shown in Figure 2.[5]

[2] Note the difference in abbreviating a million-watt hours (MWh) which is based on the International System of Units (SI) versus a million British thermal units (MMBtu) which is based on the Imperial System of Units.
[3] U.S. Energy Information Agency, Short-Term Energy Outlook (1/1/22), *Coal will account for 85% of U.S. electric generating capacity retirements in 2022*. https://www.eia.gov/todayinenergy/detail.php?id=50838
[4] U.S. Energy Information Agency, Short-Term Energy Outlook (12/7/21), *In September, the U.S. was at its lowest coal stockpiles since 1978.* https://www.eia.gov/todayinenergy/detail.php?id=50558
[5] CleanTechnica (6/5/22), *Potential Electricity Reliability Concern for Central U.S.A*, https://cleantechnica.com/2022/06/05/potential-electricity-reliability-concern-for-central-u-s-a/, U.S. Energy Information Agency*, Today in Energy* (6/3/22), https://www.eia.gov/todayinenergy/detail.php?id=52618, NERC (5/22), *2022 Summer Reliability Assessment*, https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_SRA_2022.pdf, MISO (4/28/22), *MISO projects risk of insufficient firm generation resources to cover peak load in summer months*. https://www.misoenergy.org/about/media-center/miso-projects-risk-of-insufficient-firm-generation-resources-to-cover-peak-load-in-summer-months/

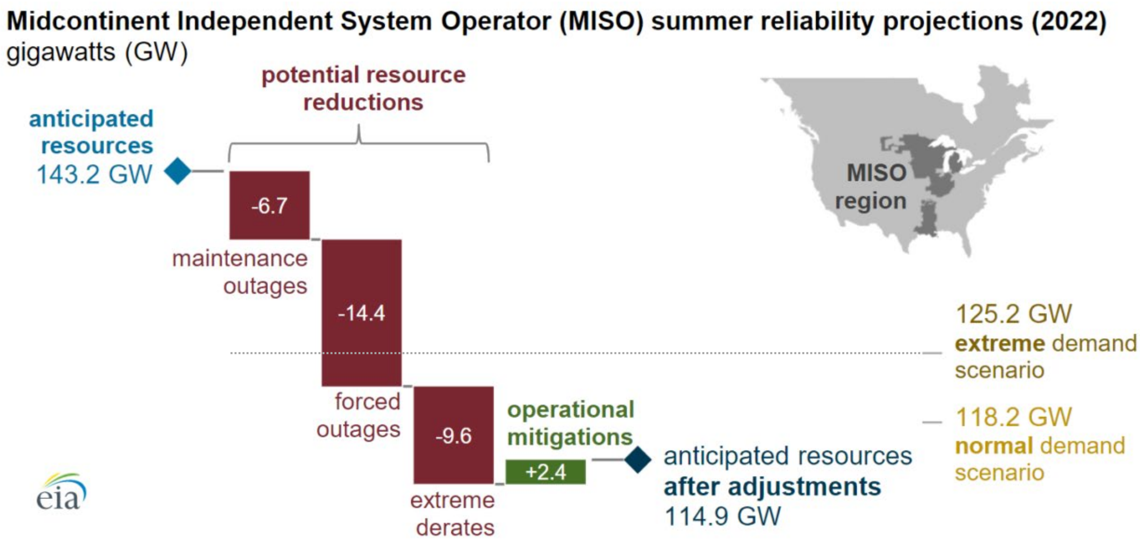

Figure 2 – MISO summer 2022 Reliability Projections.

To ensure reliability, MISO and other "balancing authorities" plan to always have more supply available than demand. As shown in Figure 2, in MISO's summer 2022 reliability projections, of the 143.2 GW of anticipated resources (at left), a reduced capacity of only 114.9 GW of generation may be available to meet between 118.2 GW and 125.2 GW of demand (at right). A shortfall will result in rotating blackout outages, most likely during a heat wave, which will likely cause loss of life and property. To anticipate electricity demand, balancing authorities produce a range of forecasts for average demand and extreme environmental conditions that used to occur only once in 10, 50, or 100 years, but are occurring more frequently. Planned and unplanned maintenance (aka forced outages) of power plants reduces available capacity as does derating generation capacity for factors such as drought, low-wind conditions, or fuel supply limitations .

Yet another factor creating unprecedented challenges in operating the grid are low and declining end-to-end, generation to load efficiencies. Efficiencies are so low that most of the fuel energy used in generating electricity, propelling transportation, and powering buildings and industry is rejected as waste heat as shown in Figure 3.[6]

[6] Lawrence Livermore National Laboratory (6/16/22), *Energy, Water, and Carbon Informatics*, https://flowcharts.llnl.gov/sites/flowcharts/files/2022-04/Energy_2021_United-States_0.png

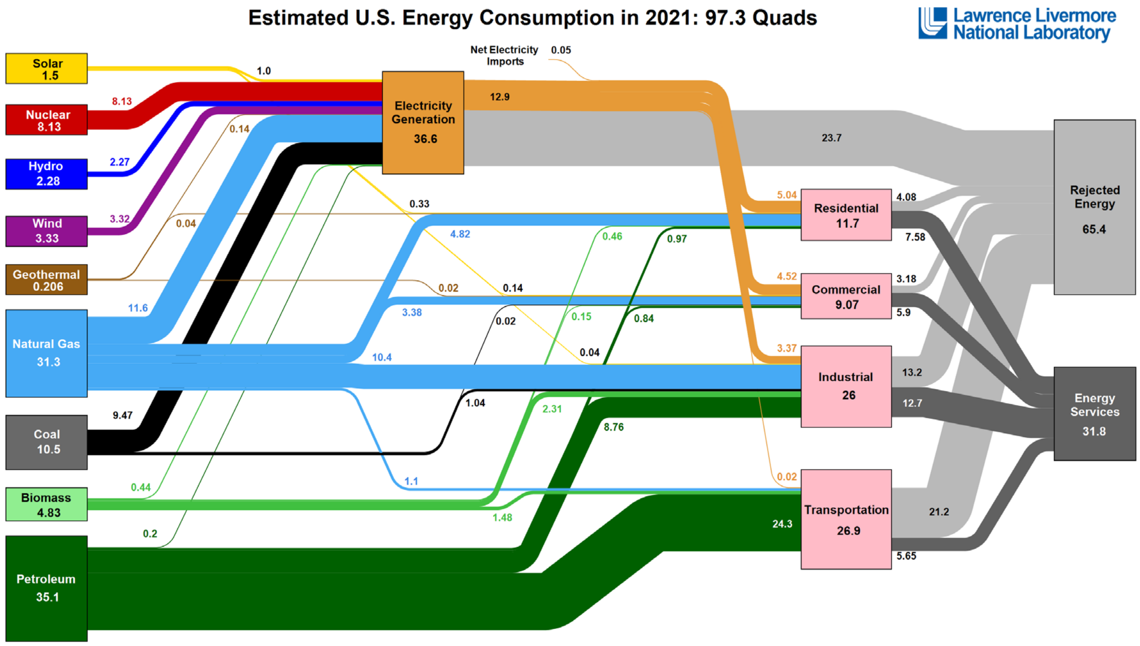

Figure 3 – 2021 Estimated U.S. Energy Consumption.

Figure 3 depicts the sources of energy (at left), how they are used, and how much is rejected (at right). Line widths are proportional to quantities of energy flows and all numbers can be roughly interpreted as a percent of total U.S. energy in each flow or sub flow. Complex interrelationships are depicted, such as the fine orange line (at lower right) denoting 0.02% of all energy consumed in the U.S. was used to charge electric vehicles.

In Figure 3, the most important takeaways are the costly inefficiencies (in light gray) that result in unnecessarily rejected energy as waste heat and greenhouse gases from: 1) electricity generation, where almost 2/3 of energy is rejected, 2) transportation, where almost 4/5 of energy is rejected, and 3) industry, where more than 1/2 of energy is rejected. Comparing the totals in light and dark gray at right, the U.S. (like most other developed nations) wastes about 2/3 of all energy used, primarily due to poor inefficiencies in electricity generation and transportation.

An alarming result of not significantly improving energy efficiencies over the last several decades is the emission of carbon continues to be colossal and will not be reduced until we have non-carbon-based electrons propelling transportation and replacing direct fossil fuel use (e.g., propane, heating oil, gasoline) in other applications.

Despite renewables and natural gas being added to the electricity generation mix and the retiring of coal powerplants, U.S. energy-related CO_2 emissions from all energy uses (electricity generation, transportation, and buildings) has not declined below 1975 levels as shown in Figure 4.[7]

[7] U.S. Energy Information Agency, Today in Energy (5/13/22), *U.S. energy-related CO_2 emissions rose 6% in 2021.* https://www.eia.gov/todayinenergy/detail.php?id=52380

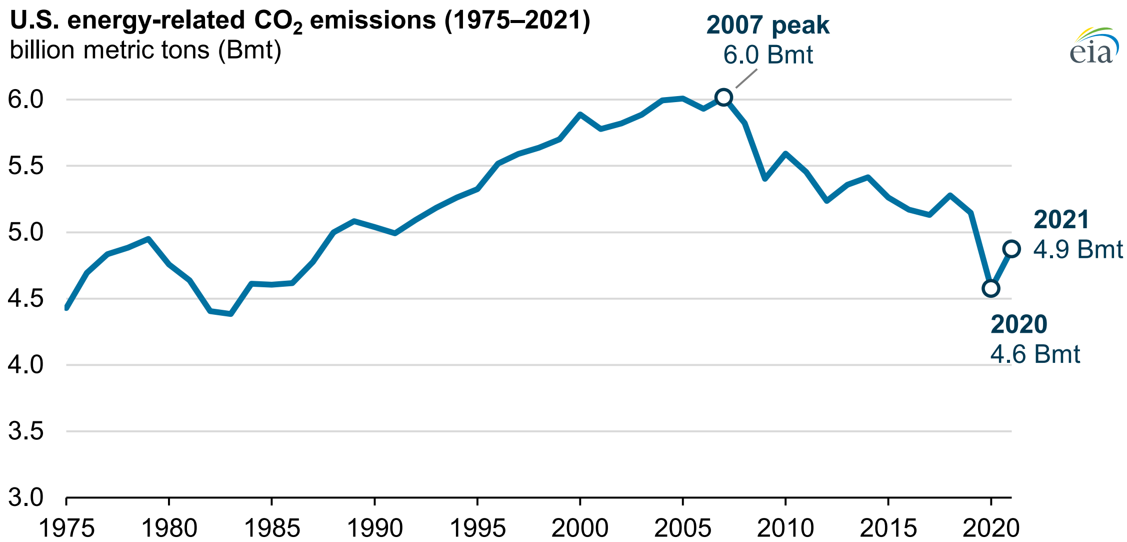

Figure 4 – U.S. Energy-related CO_2 Emissions.

In the U.S., the transportation and electric power sectors are the greatest contributors to energy-related CO_2 emissions, each responsible for roughly 1/3 of all greenhouse gas (GHG) emissions. In 2021, transportation emissions rose due to increased petroleum consumption as COVID-19-related restrictions eased. Likewise, electric power sector emissions rose due to increased electricity generation and the use of higher carbon intensity coal-based generation. In the U.S., electric power sector emissions from coal increased for the first time since 2014 (a global trend that is expected to continue for several years given natural gas supply constraints).

Exacerbating all the issues depicted in Figures 1-4 are declining energy efficiencies due to increases in extreme temperatures. On the supply side, as outdoor temperature rises, power plants, transformers, and powerlines become less efficient at moving electrons and rejecting heat. To make matters worse, on the demand side, air conditioners, the largest component of summer demand, also become less efficient as outdoor temperatures rise, causing air conditioners (AC) use more energy to keep buildings cool. This creates a death spiral: The hotter it gets, the more societies suffer by unsustainably declining efficiency, as more and more cooling energy is needed from less and less efficient power plants which are unable to meet demands for electricity. Thankfully, legislatures, regulators and grid operators are making efforts to deploy renewables and storage at utility-scale, community-scale, and premises-scale to help address spikes on the hot days due to AC loads and on cold days due to heating loads.[8]

3. Sustainability Financials

Inefficiencies undermine the sustainability of current grid operations and many other energy uses and business models, especially given the rising costs of energy. In 2019, U.S energy expenditures, the amount of money spent by consumers to purchase energy, was $1.2 trillion.[9] Considering more than just electricity, a disaggregation of energy expenses for all types of energy used over the last 50 years is shown in Figure 5.

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[8] Julie McNamara (7/9/2019), *How do power grids beat the summer heat,* The Equation, Union of Concerned Scientists, https://blog.ucsusa.org/julie-mcnamara/how-do-power-grids-beat-the-summer-heat
[9] U.S. Energy Information Agency, Today in Energy (9/9/21), *In 2019, U.S. inflation-adjusted energy expenditures fell 5%.* https://www.eia.gov/todayinenergy/detail.php?id=49476

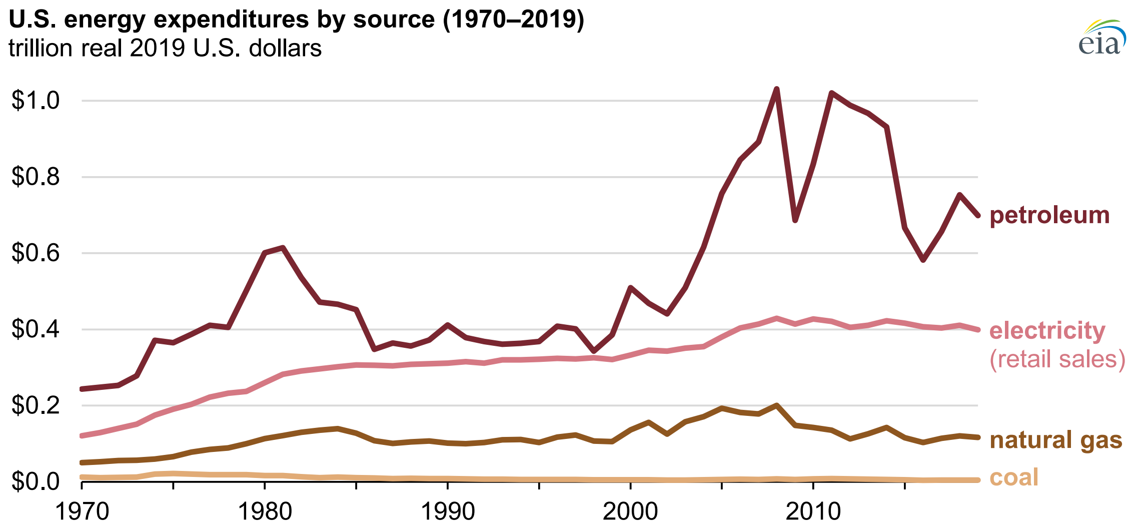

Figure 5 – U.S. Annual Energy Expenditures.

Referencing Figure 5, it is important to consider two significant yet uncharted imminent changes in trajectories: 1) cost increases attributable to the 2022 war in Ukraine have already doubled and could triple the costs of energy, and 2) the process of so-called beneficial electrification, e.g., the introduction of electric vehicles, will double or triple societies' consumption of electricity while decreasing the uses of petroleum, natural gas and coal over coming decades.[10] The product of tripling electricity costs and tripling electricity consumption could yield a near 10x increase in residential, commercial, industrial and agricultural electricity bills, and could be unsustainable in terms of costs and GHG emissions.

4. Architectural History of Cable Networks and the Grid

Today's transformative path of the electric grid is similar to that of the historical evolution of the cable broadband network. Cable networks initially used centralized headends, proprietary systems, and one-way delivery of content. Over time, two-way upgrades and distributed headends and hubs enabled the development and deployment of new services, including telephony and high-speed data. As two-way services became highly penetrated and successful, the threat of network congestion and slowdowns gave rise to traffic engineering and the development of the massively scalable world-standard cable modem.[11] Tools to detect and mitigate network congestion were needed, were developed quickly, and continue to evolve.

[10] Beneficial electrification (aka clean electrification, strategic electrification) is a term for replacing direct fossil fuel use (e.g., propane, heating oil, gasoline) with electricity in a way that reduces overall emissions and energy costs. There are many opportunities across the residential and commercial sectors. This can include switching to an electric vehicle or an electric heating system – but only if the end-user and the environment both benefit. Environmental and Energy Studies Institute (Jun 2022), *Beneficial Electrification, An Access Clean Energy Savings Program*. https://www.eesi.org/electrification/be#:~:text=Beneficial%20electrification%20(or%20strategic%20electrification,the%20residential%20and%20commercial%20sectors .

[11] Cable Television Laboratories, Inc. (CableLabs) led the effort to develop the world standard cable modem and certify interoperability. Consumers continue to benefit in the global telecommunications marketplace where vendors compete on price, functionality, and delivery schedules. An example of a powerful standard, interoperable cable modems are a thousand times faster than the proprietary cable modems they replaced and million times faster than dial-up modems.

As depicted in Figure 6, Many striking similarities arise when comparing the challenges of developing and deploying global broadband networks to the existing and anticipated challenges of developing standards-based scalable interoperable smart power grids.

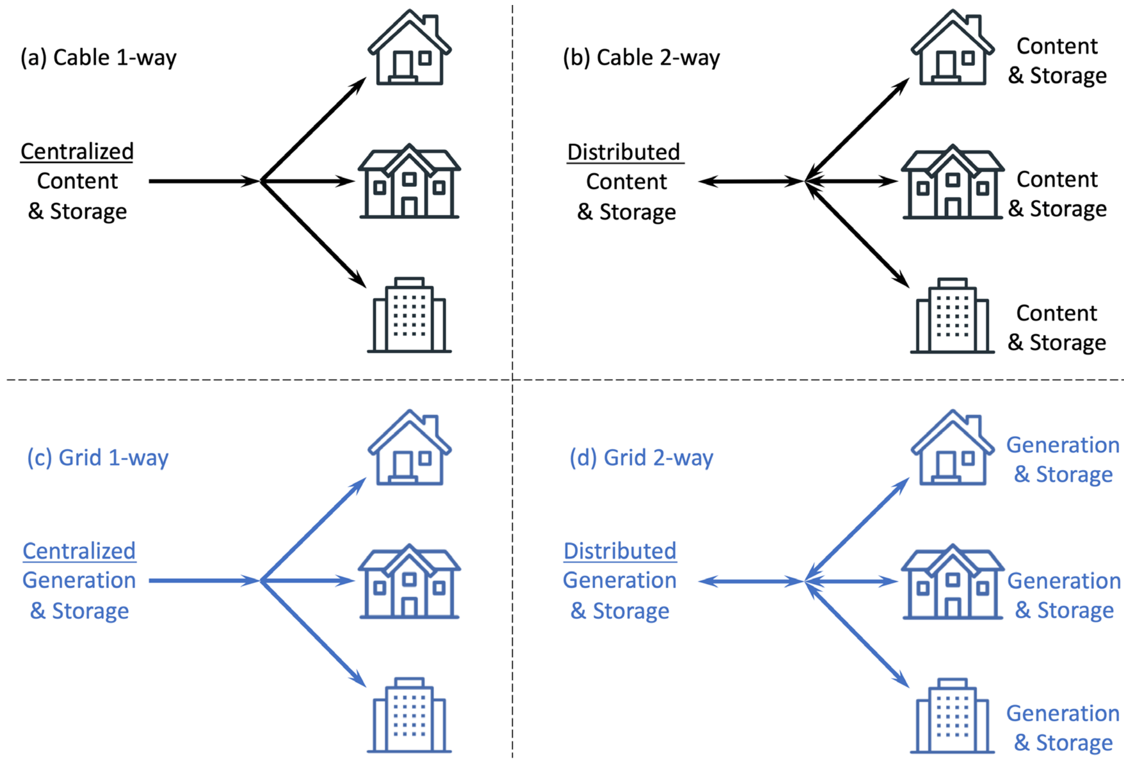

Figure 6 – Similarities in 1-way to 2-way upgrades of Cable and the Grid.

The top row of Figure 6 depicts (in black) the evolution of the cable distribution network from (a) 1-way to (b) 2-way. The bottom row depicts (in blue) a similar transition for the grid from (c) to (d). Cable's experience in transitioning to 2-way, identifying and managing congestion, can be helpful to the grid.

In the grid, the traditional model of central station generation is increasingly augmented by distributed energy resources (DERs) such as wind power, solar power, and other renewable energy technologies. DERs encompass more than electrical generators and include internet-connected batteries and electric loads that are smart in meeting user demands while time-shifting usage to operate now or later to reduce stress on the grid. DERs can choose to operate now, if there is abundant clean energy and no grid congestion issues or can operate later if there will be a more significant benefit to the grid. Some DERs, such as increasingly popular solar plus storage, create two-way flows of electrons that are managed by modulating (aka time-shifting or shaping) demands for electricity.

The process of influencing the timing of when electricity is delivered to the grid by DERs – or consumed from the grid by flexible loads such as batteries – is generally called Demand Side Management (DSM). DSM is facilitated by load shaping information provided by a power supplier in the form of a Demand Response (DR) signal.

Like in the early days of broadband, today's grid is operated with a mix of standards-based and proprietary solutions. Well-established standards include lamp sockets, wall plugs, voltages, and frequencies. Newer standards include managing DER behaviors in specific applications, such as solar inverters, vehicle chargers and building controls.[12] The most significant challenges with DERs are orchestrating and aggregating their behavior to 1) maximize the resiliency, sustainability, and affordability of the grid, and 2) detect and mitigate congested electron flows that create heat, that shortens the lifespan of grid components and impacts outages and possible loss of property, life, or both.

5. The Symbiotic Future

As consumer-based generation "prosumer" trends increase, community-augmented electricity systems will likely become commonplace for providing resilient, sustainable, and affordable energy mixes. Community-level DER management will benefit from applying standards that rapidly modernize grid technologies to create efficient energy management orchestration synergies.

Modern telecommunications and broadband internet services work smoothly because each industry has adopted open, non-proprietary interoperability standards. Likewise, looking ahead for the next 10-20 years, the grid will perform more smoothly by favoring standards-based DSM solutions over propriety DSM solutions wherever possible. Demand response (DR) programs look to incentivize customers with the ability to inject power, add or shed load at a predictive time to reduce strains on the power grid. Demand response is a grid balancing option with limited deployment and represents untapped potential that has been modeled but not proven at scale. With a total available market of billions of DR devices in the U.S., and only 10 – 15 million deployed over the last 30-40 years, there is tremendous upside for global deployments of standards-based DERs to provide DR. To that end, the broadband industry has work to do in educating utilities, legislators, regulators, and power industry vendors about new scalable standards that accelerate the development of a sustainable and resilient smart grid.

Standards for *managing* demand and *monitoring* the power grid can be used to provide traffic engineering solutions that work remarkably well. Standards-based networked DERs can speed the deployment of renewables, batteries, and smart loads, guiding them to work in unison to shape load to raise the efficiency of the end-to-end generation, transmission, and distribution (G&T&D) infrastructure. By responding to changes in forecast daily grid needs and contingencies such as failures in G&T&D, networked DERs can manage load continuously to avoid costly peak generation and to move as many electrons as possible off-peak through would-be congested areas.

Combining grid monitoring sensor data with easy access to smart meter electricity interval usage data for consumers and authorized third parties will ensure that customer responses to DR signals are recognized and compensated. Compensation will be issued for DERs such as EVs, residential, commercial, industrial, and agricultural uses that follow load shaping signals. Load shaping will be based on forecasts of load and demand as well as observations from broadband-based sensors that monitor and quantify the impact of power anomalies on the grid. Anomalies are measured in terms of power quality issues such as oscillations and spikes in voltages, sustained over/under voltages, overloaded/overheated grid components, and other distribution system behaviors, faults, and their associated risks.

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[12] Much work has gone into developing interconnection and interoperability standards that define how to assemble, configure, and connect devices to form a smart modern grid. Nonetheless, a major challenge with standards to date is that they are limited to development within specific technology domains, such as vehicle charging or air conditioning. As such, existing standards lack a complete vision for how distributed energy resources need to interact with G&T&D to deliver resilient and sustainable end-to-end grid services. While some standards are mature, technically robust, and meet the needs within a specific domain, in aggregate, they do not support optimum load shaping. The need for the ANSI/SCTE load shaping standard became apparent when assisting in the review of the U.S. Department of Energy, Grid Modernization Laboratory Consortium (Mar 2021), *Survey of Distributed Energy Resource Interconnection and Interoperability Standards*, https://www.nrel.gov/docs/fy21osti/77497.pdf

Combined analyses of customer meter data and grid sensor data will provide complementary insight into DER operations and their impact on the grid. In the near term, sensing and analysis will improve grid situational awareness and help determine and inventory the types, sizes, and locations of DERs operating on the grid today. Furthermore, sensing and analysis will identify normal and anomalous grid and DER operating states and behaviors. In the long term, sensing and analysis will be critical for asset and load capability forecasting. Having this more significant insight into grid operating states will ultimately enhance the availability and reliability of the broadband network.

6. What Broadband Offers The Grid

In 2021 the Society of Cable Telecommunications Engineers (SCTE) completed two synergistic American National Standards designed to reduce grid failures, contain electricity costs, and monetize demand response. The standards specify improved grid sensors and orchestration of electric loads via a simple information model. Separately and together, the standards improve electricity G&T&D, storage, and end-use while accelerating the adoption of electric vehicles (EVs) and resilient local power using batteries and other networked distributed energy resources.

6.1. ANSI/SCTE 267 Optimum Load Shaping for Electric Vehicle and Battery Charging

The SCTE 267 standard specifies end-to-end control of the electric power grid and commercial microgrids from generation to load, using one-way broadcast and two-way interactive signals. The standard defines how to create, transmit, and act upon a forecast optimum load shape (OLS) to manage the charging of EVs and facility batteries, as well as demands for electricity from flexible and discretionary smart electric loads.

An OLS provides grid control with a set of numbers, such as the target load for hours 1-24. The numbers in an OLS can, for example, forecast the cleanest, most efficient, and least cost electrical supply, so that all stakeholders: G&T&D entities, retail electricity providers, and consumers benefit.

Several topics are addressed in SCTE 267: 1) A generation-to-load OLS architecture is specified. 2) Based on inputs of forecast load and forecast generation from renewables, a method for producing a location-specific OLS is specified. 3) A method for managing the charging of electric vehicles is specified as an example of how any smart load can autonomously interpret and take local actions based on an OLS.

The OLS standard was created because existing siloed standards do not provide sufficient control to benefit the different needs of G&T&D. With OLS, stakeholders, including broadband providers, can reduce their electricity costs and carbon emissions by having their smart loads follow the lowest cost forms of supply. If not implemented, broadband providers will have less control over the rising cost of electric power.

Short-term benefits include creating and distributing both near and far-reaching OLS signals quickly and easily that allow intelligent devices that implement the standard to participate by shaping load. Benefits accrue in the short and long-term as more smart devices implement the standard resulting in more significant benefits for most stakeholders in the electricity value chain. The potential impact on the broadband industry is a reducing energy procurement costs and creating new revenue generating units based on managing the charging of cable customers' vehicles and batteries and flexible uses of electricity.

An OLS signal is created, transmitted, and acted upon, as shown in Figure 7. For example, an OLS Producer (typically an entity associated with an electricity supply or control system) ingests forecasts of load, renewable generation, and costs. The Producer then uses 1-way and 2-way networks to distribute OLS signals to OLS Consumers (devices that manage the consumption of electricity).

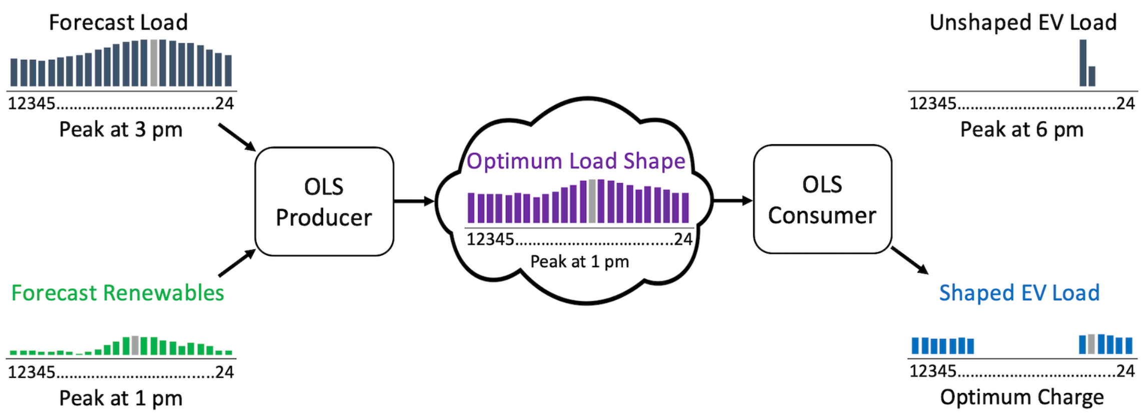

Figure 7 – Optimum load shaping system.[13]

An OLS Producer may employ various techniques to create an OLS signal. An algorithm may minimize costs and optimize the utilization of renewable generation. As depicted in Figure 7, the OLS Producer (at left) is a processor that obtains time-series signals such as load and renewable generation forecasts. The OLS Producer may: 1) subtract the forecast renewable generation from the forecast load to produce a net generation[14] shape, 2) flatten net generation to maximize the efficiency of the mix of thermal generators, and 3) add the forecast renewable generation and the flattened net generation together to create the OLS signal. These steps and the resulting actions of OLS Consumers are described in detail in the SCTE 267 easy-read standard.

A single entity may be a Producer and a Consumer, for example, an entity that consumes an OLS signal from an upstream Producer such as a utility may produce localized OLS signals and share them with several downstream consumers. Continuing the example, a building energy controller may consume an OLS signal from a utility and send a modified OLS signal to water heaters, thermostats, and vehicle chargers to coordinate time-shifting of demand among appliances to reduce energy costs and optimize the performance of a home or business.

The ANSI/SCTE 267 standard makes possible the shaping of load across small and large geographic areas. For example, Figure 8 is based on the simulation of the serving of the Electric Reliability Council of Texas (ERCOT) and shows the hourly generation based on actual load (at top) and daily optimum load (at bottom) on 20–26 Aug 2005.[15]

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[13] Source: Society of Cable Telecommunications Energy (2021), *ANSI/SCTE 267: Optimum Load Shaping for Electric Vehicle and Battery Charging*, https://www.scte.org/standards/library/catalog/

[14] In this context, net generation refers to the generation required from thermal power plants to meet demand for electricity after accounting for the contribution of renewables.

[15] The primary author's generation-to-load simulation estimated the impact, in terms of production costs and CO2 emissions, attributable to the joint optimization of electric power generation and flexible end uses to support increasing penetrations of renewable energy. Newly conceived, evaluated, and foundational in developing the ANSI/SCTE 267 American National Standard was a transaction-less, yet continuous demand response system based on a day-ahead optimum load shape (OLS) designed to encourage Internet-connected devices to autonomously and voluntarily explore options to favor lowest cost generators – without requiring two-way communications, personally identifiable information, or customer opt-in. Boundary conditions used for model calibration included historical

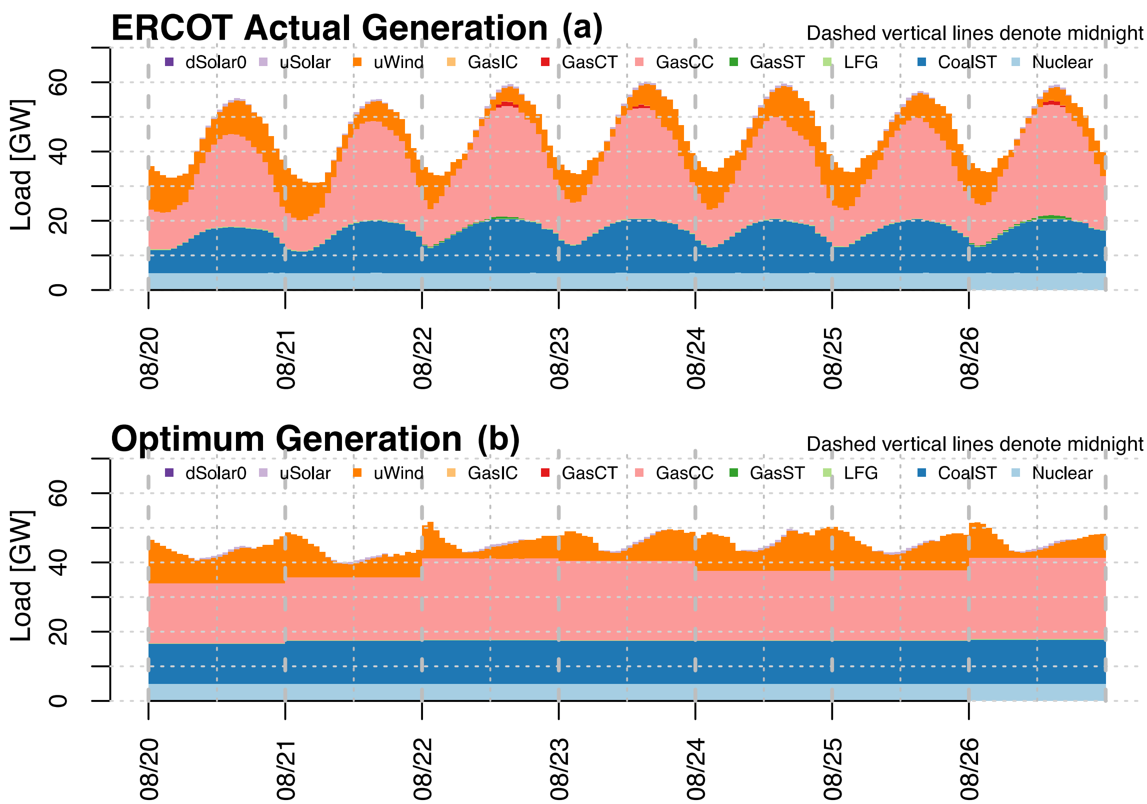

Figure 8 – ERCOT Hourly Generation Based on Actual and Daily Optimum Load.[16]

In Figure 8, production cost and CO2 emissions were calculated for the unshaped actual historical hourly load (at top), and for the same load had it been optimally shaped over seven days. As expected, the minimum production cost was achieved when power plant output was constant, depicted as flat lines for thermal generation, as shown for each hour of 20–26 Aug 2005 as shown at the bottom of Figure 8. The week of 20–26 August is of interest as: (a) it was the hottest week of 2005 with over a TWh of energy delivered each day, and (b) many of the 600+ thermal generation power plants in Texas were active and could benefit from higher efficiencies that would result from higher capacity factors.[17]

The primary author's research, funded by the U.S. Department of Energy and conducted in-residence at National Renewable Energy Laboratory (NREL), shows that fixed and mobile batteries are the most

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weather, residential building stock construction attributes, home appliance and device empirical operating schedules, prototypical power distribution feeder models, thermal generator heat rates, startup and ramping constraints, and fuel costs. Results of an hourly-based annual case study of Texas indicate a 1/3 reduction in production costs and a 1/5 reduction in CO2 emissions are possible.

[16] Robert Cruickshank, Ph.D. thesis, University of Colorado Boulder (Sep 2019), *Estimating the value of jointly optimized electric power generation and residential electrical use.* https://scholar.colorado.edu/concern/graduate_thesis_or_dissertations/x059c851q

[17] In generation, capacity factor is defined as the amount of energy actually produced divided by the maximum amount of energy that could have been produced at full output power. In transmission and distribution, capacity factor is defined as the actual amount of energy moved divided by the maximum amount of energy that could have been moved.

critical DERs to be networked first.[18] The trend of increasing electric vehicle and in-building batteries is an opportunity to be addressed. To that end, e-Radio USA manufactures an SCTE 267-compatible EV charging adapter with various connectors that ensure backward and forward compatibility with all types of EVs as shown in Figure 9. Any kind of electric vehicle can plug into the EV Charging Adapter, which plugs into any EV charger. The adapter's green light indicator illuminates when the EV Adapter is receiving an authenticated FM, satellite, LTE or Wi-Fi signal and is working correctly. The EV charging adapter optimizes charging in response to grid signals, ensuring that wind, solar, and low-cost energy sources are maximized – and can be configure-less when used in broadcast applications. The vehicle owner can use the vehicle's standard control system to override the OLS signal if necessary to assure immediate charging.

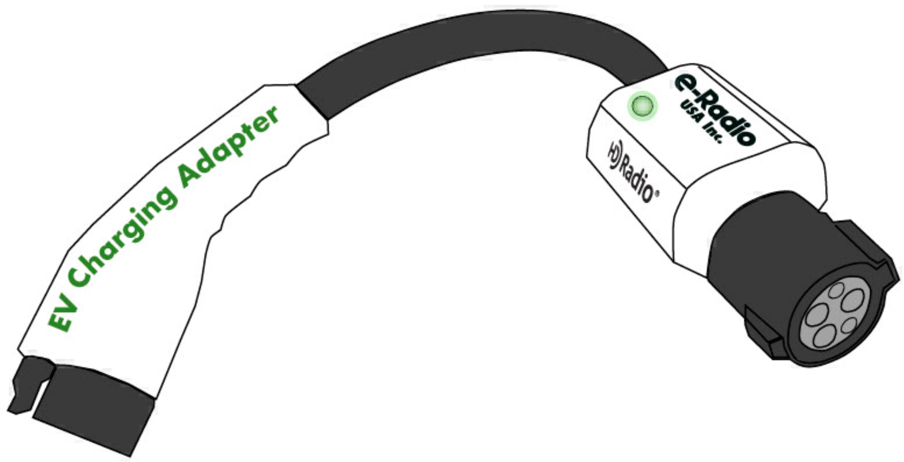

Figure 9 – Electric Vehicle Charging Adapter.[19]

There are evolving accessibility and information security concerns to be considered and addressed to protect consumer privacy and grid security. To that end, the broadcast one-way delivery method for OLS signals may use multi-network authentication; thus, DERs do not add or shed load until each autonomously confirms the identical OLS signal is being received by multiple sources and/or networks. For example, a DER such as an EV charging adapter would verify that the same guidance signal is being received via FM radio, satellite, and/or the Internet. In all cases, the security of DERs, the data collected, security of software, and algorithm development processes must be addressed.

As part of DER participation, the bulk power system will benefit from a three-level battery hierarchy that manages the flow of electrons within and across transmission, distribution, and consumer networks. Transmission-scale and distribution-scale batteries provide increased system resiliency and pay for themselves with resiliency and with revenues from capacity, energy, and frequency response. While utilities and energy market participants are likely to directly control batteries located in transmission and distribution (T&D) networks, most batteries will be premises-based, consumer-owned, and can be voluntarily controlled by SCTE 267 OLS signals to the benefit of all three G&T&D realms.

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[18] Robert Cruickshank, Gregor Henze, Anthony Florita, Charles Corbin & Killian Stone (2021), *Estimating the value of jointly optimized electric power generation and end use: a study of ISO-scale load shaping applied to the residential building stock*, Journal of Building Performance Simulation, DOI: 10.1080/19401493.2021.1998222

[19] Power Networks, LLC, Submission to Public Utility Commission of Texas (Jun 2022). Image courtesy of e-Radio and Xperi https://drive.google.com/file/d/1CStDFzorjrME8Czf49TqVMsHj7fyu0SZ/view?usp=sharing

SCTE 267 OLS signals are widely usable due to their ability to guide battery charge and discharge. OLS signals can guide a mobile or fixed battery to modulate charge/discharge over time. Figure 10 depicts battery charging and discharging wherein the charger voluntarily and autonomously uses the OLS signal (in blue) to inform charging and discharging profiles (in orange); a sinusoidal OLS signal illustrates the concept.

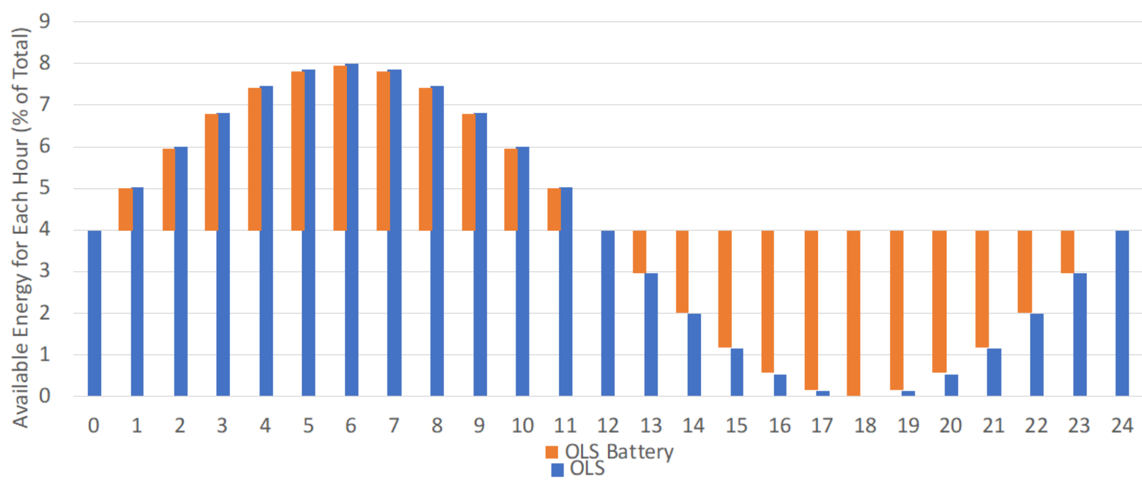

Figure 10 – Hourly Optimum: 1) Load Shape, 2) Charge/Discharge Shape.[20]

In Figure 10, a battery charge controller receives an OLS signal (in blue) and then autonomously draws a horizontal line that divides the signal into charging and discharging intervals (in orange). The timing of charging/discharging is modified daily and hourly based on the forecasted availability of wind and solar power, actual grid contingencies, power system and user needs. When severe weather is expected, batteries can choose to enter "storm mode" and charge up to fully prepare for a potential grid outage.

Congestion detection and mitigation are increasingly crucial as beneficial electrification results in distribution networks connecting to more loads, particularly more numerous and higher capacity EV chargers. Once congestion is detected by location-aware DERs, it can be mitigated using a "local" OLS signal to raise the carrying capacity and extend the lifespan of a distribution network, as shown in Figure 11.

[20] Robert Cruickshank Associates (Dec 2021), Presentation to SCTE Microgrid working Group.

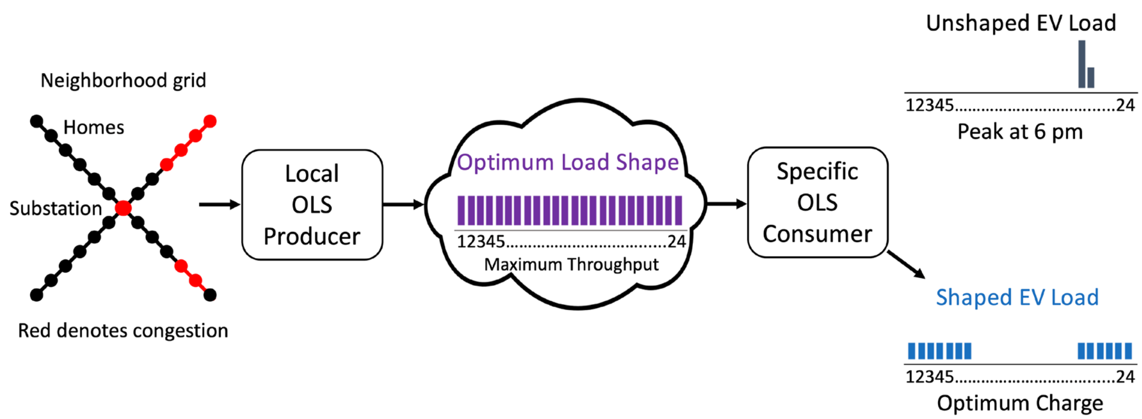

Figure 11 – A "Local" Load Shape to Mitigate Grid Congestion.[21]

Local load shaping is something broadband providers can be very good at and accomplish very quickly. Per SCTE 267, some DERs, like EVs, can choose to share their latitude and longitude when checking for load shapes. In Figure 11, mitigation of congestion (segments and locations shown in red at left) is achieved by modulating loads to utilize fully, but not overload, a distribution circuit using a local load shape for loads downstream of T&D congestion points. In the center of Figure 11, the flat purple shape guides DERs to adjust their load to raise the capacity factors of congested T&D network segments.

SCTE 267 and 271 were designed to work separately and together. For example, voltage sags sensed by an SCTE 271 sensor can indicate congested segments – which can deliver more energy when SCTE 267 local load shapes guide DERs to favor off peak electricity usage.

6.2. ANSI/SCTE 271 Power Sensing in Cable and Utility Networks

The SCTE 271 standard specifies provides precision, sampling rate, and configuration requirements if vendors measure and report voltage and current in hardware and software to enable advanced power sensing in cable and utility networks. Included are requirements for sensing and communicating power quality observations from both the 60/75/90 VAC quasi-square wave HFC network and the 120/240 VAC supply from the electric power grid. For systems that support remote communication of measurements, requirements for the control plane and communications security are specified. The specification does not require any particular measurements. Still, if supply voltage and current are measured, it specifies how those measurements are made to benefit the grid and broadband network operations.

The development of the SCTE 271 sensing standard was motivated by successes in the U.S. Department of Energy (DOE) Situational Awareness of Grid Anomalies (SAGA) project underway at the NREL and CableLabs since October 2019. Early in the SAGA project and while developing the Gridmetrics® Power Event Notification System (PENS), the NREL and CableLabs team recognized that the existing sensing capabilities specified in the ANSI/SCTE 25-3 standard were 1) out of date, and 2) could be updated to enrich grid and broadband Proactive Network Maintenance by finding congestion and loose seizure screws, high-impedance faults, and other voltage and current glitches and anomalies that could lead to grid and HFC service outages.

[21] Source: R Cruickshank, A Silverstein, A von Meier (Jun 2022), The Society for Standards Professionals, Standards Engineering Journal, *Broadband standards to manage and monitor the grid.* https://www.ses-standards.org

For grid providers, a timeless and ever-important question is, "How many EVs and batteries can a distribution segment or transformer support before there is an increased risk of congestion and premature equipment failures and outages due to a thermal overload? For example, what would happen if many consumers in a community traded in their internal combustion engine vehicle for an EV? Would the community be unable to charge the new load profile with today's "plug it in and take it" model? Furthermore, how could signaling and sensing comfortably help answer that question with a resounding YES? Both of the SCTE standards address these needs.

Today, congestion visibility in sensor-starved distribution networks can be achieved by deploying power quality sensors, such as SCTE 271-based sensors. Once detected, congestion can be mitigated using local OLS signals to avoid slowdowns/failures on the grid.

Many forms of grid measurement work together to ensure a resilient and sustainable power grid. As shown in Figure 12, Advanced Metering Infrastructure (AMI) provides kW demand and kWh consumption at customer meters, typically reported at 15-min resolution. Supervisory Control and Data Acquisition (SCADA) provides voltage or current magnitudes, reported at a resolution on the order of several seconds. Phasor Measurement Units (PMUs) provide voltage or current magnitudes and phase angles, frequency, and derivative quantities reported roughly every cycle (25-120 Hz). Point-on-Wave (POW) sensors, provide voltage or current magnitudes and phase angles, frequency and derivative quantities, and 256 to 1 million samples/sec of voltage or current waveform, reported for a short duration or on a continuous monitoring basis. SCTE 271-compliant sensors implement POW functionality to provide unprecedented visibility to grid issues.

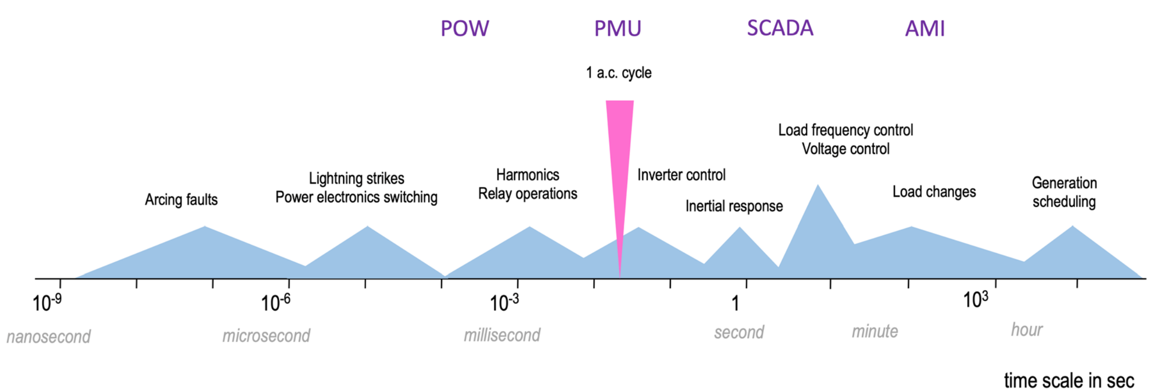

Figure 12 – Time Scales for Electric Grid Monitoring and Control.[22]

Referencing Figure 12, POW sensors provide the finest temporal resolution of power quality information to communications providers, utilities, and others. POW sensors stream data in real-time, enabling the rate of change of frequency and sine-wave goodness-of-fit to be calculated remotely from the measuring network element. This approach is favored by utility engineers and operations staff as it is robust in situations with high electrical noise and distortion, where traditional assumptions about sinusoidal waveforms are not met.

A key feature of SCTE271-compliant sensors is their ability to stream uncensured waveforms for cloud-based analysis aided by operations experts and machine learning. Utility engineers are reacting positively

[22] International Council on Large Electric Systems (CIGRE) Webinar Academy, Alexandra von Meier (Oct 2020), *AI on the grid: Understanding PMU data.* https://www.youtube.com/watch?v=qRAPYVtC2zM and https://iclesunc.memberclicks.net/assets/AI%20on%20the%20Grid%20%28Day%201%29.pdf

to the availability of POW streaming waveforms that aid in detecting vegetation strikes and other grid failure signatures. By using human-in-the-loop machine learning, failure signatures can be rewound in time to improve early detection of grid and broadband network physical layer issues and provide a quantum leap beyond current best practices for identifying and predicting network issues.

SCTE271-compliant sensors do not over compress or distort data before backhauling to the cloud. With voltage and current precision of 0.02% per unit and sampling rates of 10 ,000 samples per second, SCTE-217 sensors preserve anomalies such as the voltage spike depicted in top panel of Figure 13.

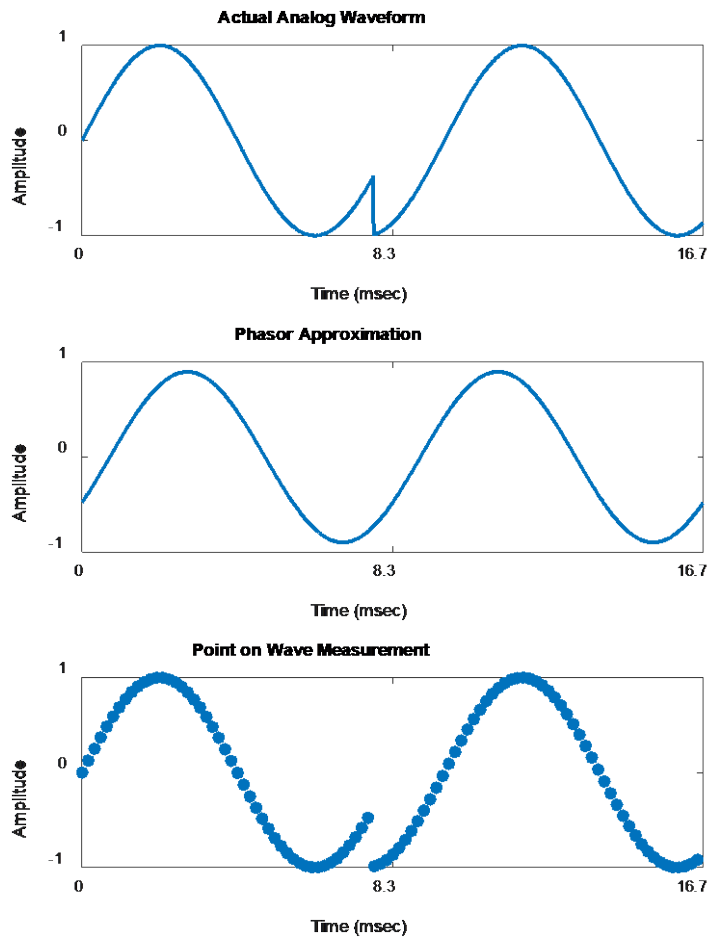

Figure 13 – Analog Waveform, Utility Capture and Broadband Capture.[23]

Figure 13 shows an actual analog wave form (at top), a phasor approximation commonly used in utility best practices (in middle), and a SCTE 271-based POW capture (at bottom). Note the glitch in the actual waveform is not observed by utility best practices that assume the underlying alternating current signal is a perfect sine wave –but is accurately observed by POW measurement.

7. Conclusion and Next Steps

Around the world, the aging and frail bulk power grid is weakened by a confluence of factors that include inefficiencies, fuel scarcities, unbridled demand, and increasingly severe and unpredictable weather.

[23] North American Synchrophasor Initiative (3/20/2020), Technical Report: High-Resolution, Time- Synchronized Grid Monitoring Devices, Alison Silverstein, Alison Silverstein Consulting, Dr. Jim Follum, PNNL

Temperature extremes add enormous demand while lowering the efficiency of generation, transmission, distribution, and end use. Costs are skyrocketing, and the impacts of outages are more cataclysmic due to our growing dependency on old and new electrically powered technologies. Moreover, there is a lack of consumer adoption of energy efficiency and automation.

The cable broadband industry has enormous opportunities to monetize critically essential capabilities for the evolving grid. New SCTE standards for managing and monitoring the grid enable relatively rapid transformational opportunities that improve resiliency and sustainability on a global scale. The power and broadband industries should build out SCTE 267 and 271 grid infrastructure to maintain business continuity, contain energy costs, and create new business opportunities.

Rising financial and environmental costs can be thoughtfully contained. New operations and business models can provide additional revenues from delivering load shaping signals and grid sensing as a service. Cable's established and evolving playbook in traffic engineering informs the roadmap for modernizing the grid. A symbiotic future of the grid and broadband networks is possible and beneficial.

Likely outcomes point the way for collaboration, such as:1) renewables will continue to be added to the generation mix, 2) the retirement of dispatchable thermal generation and the rise of renewables will create a growing void in controls that balance electricity supply and demand., and 3) balancing supply and demand on the grid will be managed and monitored across multiple timescales. As opportunities continue to mature, the SCTE 267 standard should be pro-actively updated to support load shaping in seconds and minutes to complement the hourly and daily timescales already implemented.

Abbreviations

ANSI	American National Standards Institute
DERs	distributed energy resources
DR	demand response
EIA	U.S. Energy Information Agency
EV	electric vehicle
G&T&D	generation, transmission and distribution
GHG	greenhouse gas
MISO	U.S. Midcontinent System Operator
MMBtu	Million British thermal units
MWh	Megawatt hour, a million-watt hours
SCTE	Society of Cable Telecommunications Engineers
T&D	transmission and distribution

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