# SOLVING FOR THE REAL ZERO GRID

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## Introduction

Regulators, politicians and customers seem to be reaching a consensus. The future of electricity will have a net zero, and eventually, real zero carbon content. Perhaps, even by 2050.

Net zero energy is defined as "the generation of electricity from non-carbon generating resources like nuclear, hydro, wind and solar with allowances for government approved off-sets and credits versus real zero energy which does not include the theoretically based off-sets and credits. Net zero or real zero energy by 2050 has dramatic implications on the current planning, design, operations and maintenance of the electric transmission and distribution (T&D) grid that delivers that energy.

This whitepaper is part of the "Solving For" series that will propose and discuss innovative solutions for challenging issues and goals that require a safe, reliable, resilient and affordable T&D system to meet said objectives.

Real zero energy by 2050 will include some basic assumptions:

Real zero energy will be achieved during massive of electrification of mobility, space conditioning and commercial and industrial (C&I) processes. Some predict doubling or tripling the current national peak generating capacity of 13,000,000 MegaWatts.

Real zero energy will require that substation and telecommunications equipment be upgraded in capacity and capability to support massive electrification.

Real zero will require underground distribution for levels of reliability and resilience needed for small scale distributed energy resources (DER) that support massive electrification

Real zero energy will require new nuclear and existing big hydro to provide base load spinning mass for system stability and some degree of fast generation ramping with hydro and pumped storage where available. Otherwise, ramping will be conducted with new and existing high efficiency natural gas turbines.

Real zero energy will require upgrading existing transmission capacity to support the new nuclear, huge amounts of remote utility-scale renewables, and existing big hydro. Transmission capacity will be developed using existing rights of way with dynamic line rating (DLR), advanced composite conductors, and high voltage direct current (HVDC) conversions. New high voltage transmission will be located in existing transportation corridors such railroads and interstate highways and will likely be underground and/or HVDC.

Real zero energy will use Artificial Intelligence (AI) to plan and design the T&D system. Sensors on everything will provide a rich, real-time, cyber secure data source for AI algorithms that efficiently deliver the cleanest and most affordable source of generation while enhancing safety, reliability, and resiliency of the grid.

Real zero energy will have the benefit of new “Wild Card” technologies between now and 2050. Advancements in material sciences will lead to superior storage media, working fuel cells, 3D design and printing, robots and more.

Real zero energy will use FERC 2222 and Net Zero Energy building design as a “warm up” in this decade for small scale DER technologies and applications that help to promote the safe, reliable and affordable development of a carbon free generation system and grid that can deliver it.

## Massive Electrification

Electrification is sweeping through America. The application of safe, reliable, affordable and clean electricity claims many benefits. Electrification brings communities, large and small, positive economic development, better transportation (mobility) and innovative, emerging technologies across a broad spectrum of community infrastructure and services.

Electricity is safe. Numerous design codes and construction, operations and maintenance best practices make electricity safe.

Electricity is reliable. Across America, the electric grid is 99.97% reliable according to the Galvin Electricity Initiative.

Electricity is relatively inexpensive. According to the US Commerce Department, electricity represents only 1.5-2.0% of household expenditures per year.

Electricity is getting cleaner. According to the American Public Power Association (APPA) as of February 2023, America has nearly 1.3 million megawatts of generation capacity. The largest fuel source for this capacity is natural gas (43.9%), followed by coal (17%). Wind, nuclear, and hydro together account for more than one-third of capacity and solar has added than 38,000 MW since 2020.


Electric vehicle charging station needs a robust grid and telecommunications system supported by artificial intelligence

## Substations and Communications

Substations will need to be bigger and telecommunications more robust.

Data scientists, engineers and planners need to start to prioritize and schedule the upgrade and doubling of capacity of existing and future substations and strongly consider building a private broadband telecommunications network with a dedicated utility spectrum.

An upgraded and hardened substation will be a key part of a new, reimagined microgrid.

Urban open-air substations that occupy all the available real estate must be converted to gas insulated switchgear (GIS) substations and suburban or rural substations with adequate real estate must have their ultimate build-out doubled in scope. Installing gates and fences, ground grids, conduit systems, control house structures and security measures for the ultimate build-out should be evaluated. Load growth due to massive electrification and data centers, high tech manufacturing, hydroponics and cryptocurrency mining occur in hard to predict parts of the service territory and require rapid deployment of reliable and redundant electric service. Substations with long lead time equipment, especially major transformers, must be ready for customers and not impede load and economic growth.

Likewise, the telecommunications technologies that support the substations and the ability to gather rich data sources from transmission and distribution assets and customer locations need to be built concurrently. Several major utilities have started to build out their own private 900mHz dedicated spectrum services to include Ameren, SDG&E, LCRA, Xcel Energy, Evergy, Dominion and others. A robust, private broadband network will help electric utilities build and maintain a real zero T&D grid in the years approaching 2050.

A robust communications network will be required for the Real Zero Grid to include underground fiber and private spectrum utility broadband.

Substations in a real zero grid will be part of a newly defined microgrid-like arrangement that supports critical infrastructure and customers with more onsite capacity, some storage, robust broadband connections, and dedicated underground feeders or transmission.

## Underground Distribution

We need a 21st Century grid to deliver real zero generation resources and that grid must be underground.

Undergrounding offers several advantages compared to overhead lines to include significantly reduced vulnerability to extreme weather events like tsunamis and floods, lightning, hurricanes, and wildfires. By eliminating the impact of future fires, severe weather conditions and reducing other potential outages caused by falling tree limbs or vegetation contact, car hit poles, birds and rodents, mylar balloon impacts, ground line wood rot and more, undergrounding contributes to a much more reliable and resilient electric grid.

The industry defines reliability with outage duration and frequency while resilience is defined as the ability to withstand a high impact, low probability (HILP) event with little or no customer outage. Reliability is measured in outage minutes and resilience is typically measured in days. Underground provides a much more resilient system and is the proven level of performance that real zero energy will require

## Big Generation

Our industry needs nuclear power to achieve ambitious real zero goals. The Southern Company has commissioned the 1100MW Plant Vogtle Unit 3 and is working on commissioning Unit 4 at great expense and schedule overruns. But, they did it.

The most promise for nuclear in the United states is held in small modular reactors (SMR) or advanced reactors planned by PacifiCorp, part of Berkshire Hathaway. Nuclear is a key part of PacifiCorp"s 2023 Integrated Resource Plan (IRP). The advanced nuclear resources that appear in the plan represent a promising future for our employees and communities in rural Utah and Wyoming," said Rick Link, senior vice president of resource planning, procurement and optimization at PacifiCorp. "As we transition to a net-zero energy future, it is important to leverage the experience, skills and dedication of the communities that have supplied our energy needs for the past century."

Big hydroelectric generation from existing dams particularly in the West and New York state represents approximately 6% of the total generating capacity of the United States and approximate 38% of the renewable generation. Hydroelectric generation and pumped storage resources will continue to be part of a clean energy mix for decades to come.

New utility-scale renewable wind and solar has grown dramatically in recent years. Add new storage technologies in these remote sites and the demand for daily, seasonal and annual increased transmission capacity is strong. Even with abundant, local DER's the real zero grid will need a robust transmission system.

## Big Transmission

A megatrend in our industry is that will we get more capacity from existing transmission rights-of-way (r/w). Routing and permitting new major transmission corridors can take 10 -15 years as evidenced by Sun Zia, TransWest Express and some of the larger lines in California. In New England, the Northern Pass Transmission Project applied to the DOE for a Presidential permit to construct, operate, maintain, and connect a high voltage direct current (HVDC) electric transmission in October of 2010. Northern Pass failed to get needed approvals and was replaced by the yet unfinished New England Clean Energy Connect (NECEC). New long-distance transmission will likely be HVDC and will be sited in railroad and highway r/w to expedite routing and permitting challenges. In these transportation corridors, the transmission will also likely be underground. Until this new transmission is built, we will use dynamic line rating (DLR) and retrofit corridors with advanced composite conductors.

Dynamic Line Rating (DLR) DLR is a technology that allows real-time monitoring and assessment of transmission line capacity based on thermal capacity of transmission lines during prevailing weather and environmental conditions. Unlike traditional static line ratings, which are conservative and fixed, or only seasonally adjusted, DLR takes into account factors such as conductor tension and temperature, air temperature, wind speed, solar radiation, and humidity to determine the safe operating limits of transmission lines more accurately. The traditional static line ratings are typically determined based on conservative scenarios, assuming higher temperatures and other unfavorable conditions. As a result, transmission lines are often underutilized during most conditions to prevent potential overheating, violations of minimum ground clearances, or long-term conductor damage during extreme weather events. DLR will maximize available transmission capacity (ATC) for the short run.

Several utilities across America and the world are having great success in expanding ATC by using advanced compost core conductors that allow more ampacity to flow through a same or smaller sized cross-section when compared to steel core conductors. Retro-fitting existing lines to increase ATC without changing structures is commonly done at American Electric Power. Likewise, NV Energy is retro-fitting heavily loaded urban lines and is building some new transmission lines with advanced conductors that have more capacity to accommodate potential load growth due to electrification. Advanced conductors have distribution applications as well.

Large underground and undersea HV and EHV cable projects like this project at SCE are becoming more common in the T&D industry.

## Artificial Intelligence

Artificial Intelligence (AI) refers to the ability of a computer or machine to perform tasks that would normally require human intelligence, such as learning, problem-solving, and decision-making. There are different types of AI, ranging from simple rule-based systems to more complex machine learning algorithms that can learn and adapt over time.

AI, like the human brain, functions around "pattern recognition." As a child, we learn by using our five senses to communicate to our brain. Over time, our brain recognizes the look, feel, smell, sound or taste of an infinite number of people, places and things. With today's advanced computing technology and massive amounts of data storage, a computer can do the same thing. AI is, therefore, defined by Webster's Dictionary as "a branch of computer science dealing with the simulation of intelligent behavior in computers: the capability of a machine to imitate intelligent human behavior."

Ubiquitous data sensors can be used on the T&D grid and on customer premises in several ways to maintain and improve the safety, reliability, and resiliency of the decarbonized grid. Data sensors can be used to monitor the electric transmission and distribution system in real-time, providing utilities with instant data that can be turned into information on the condition and performance of their infrastructure. This can help utilities predict and identify potential issues or problems before they become serious and take proactive measures to maintain the system's health and reliability. Data sensors can be used to discover wildfires, downed conductors, failing cables, voltage anomalies and faults in the T&D system. By leveraging the power of data, utilities can improve their operations and support the development of a real zero grid that continues to meet the needs of consumers and communities.

June 2005 wildfire in southwest Phoenix, Arizona area causing out-age on six circuits of 500kV, 345kV and 230kV transmission lines.

## Wild Card

Real zero energy will have the benefit of new "Wild Card" technologies between now and 2050. Advancements in material sciences will lead to superior storage media, working fuel cells, digital twins, 3D design and printing, superconductors and more.

## Storage

Lithium ion battery technology will be replaced with new storage technologies in the next decade. The rare and critical Earth elements that make Lithium Ion batteries like Nickel, Lithium and Cobalt are not sustainable in the long run. Hydrogen storage may be part of that solution.

## Fuel Cells

Bio-fueled fuel cells or hydrogen fuel cells can be used to generate electricity, providing a clean and efficient alternative to traditional combustion-based power generation. In addition, fuel cells can be used to power electric vehicles, homes, schools and businesses. Bio-fueled fuel cells or hydrogen fuel cells can be used to balance the electric grid by providing a flexible source of power that can respond quickly to changes in demand or supply. Hydrogen fuel cells can be used to provide backup power during times of peak demand, reducing the need for fossil fuel-based peaking plants. And, hydrogen fuel cells can be used in addition to batteries to power remote sensors and monitoring equipment on the T&D system. Finally, hydrogen fuel cells can be part of a portfolio of generation, storage and demand side management tools used to successfully operate and maintain net zero energy buildings and eventually the real zero grid.

## Digital Twins

The digital twin is a multi-dimensional model or representation of a physical asset, infrastructure system or city that provides valuable information about asset location, cost, condition and performance. The digital twins is constantly updated from multiple human, robotic and sensory data sources. They are not a static three (3) dimensional (x, y, z) model and can include dimensions for schedule (4D), cost (5D), ESG scoring (6D) and more. The digital twin of the overhead and underground electric transmission and distribution system is a virtual replica of the physical system. It is a computer-based model that incorporates data from various sources, such as sensors, meters, robots and other monitoring equipment, to provide a detailed and accurate representation of the electric system. The digital twin can simulate various design scenarios such as the integration of distributed resources like renewables, storage, electric vehicles (EV) or fuel cells as data scientists, planners and engineers model and prioritize the development of the real zero grid.

The digital twin can assist operators with condition assessment and predictive analyses of asset condition as part of an asset management program or asset health center. This can help utilities optimize their asset management strategies and extend the life of their increasingly loaded substation equipment. Further, the digital twin can simulate asset performance during high impact-low probability (HILP) events such wildfires, ice storms, tornadoes or even cyber-attacks. The digital twin of the electric T&D system provides utilities with a powerful tool for optimizing their operations, improving the reliability and resiliency of the grid and lowering the cost of the asset over its useful life. This leverage allows utilities to apply other advanced technologies to build out a safe, reliable and resilient real zero grid. One such technology is 3D printing and construction.

### 3D Printing

3D printing and construction has the potential to impact the electric T&D industry in several ways. 3D printing can be used to create durable replacement parts on the jobsite for some T&D equipment and potentially reduce downtime and repair costs. Plastic parts, panels or enclosures in substations or in manholes will be the starting point. As print feedstock metallurgy advances this opportunity will grow significantly and improve the ability to solve some critical path supply chain issues with a printed part rather than a long lead time part from a faraway factory. The real zero grid will need a supply chain that delivers parts and components rapidly, perhaps in real time.

### Superconductors

Material science break throughs will give our industry superconducting technology that will be safe, reliable and affordable in the next decade. Replacing old underground high-pressure fluid filled (HPFF) transmission lines in heavy urban environments will be a perfect application. ComEd in Chicago has piloted this technology with reasonable success.

## FERC 2222

Societies around the world strive to achieve carbon-free generation portfolios and a real zero grid and access to integrated DERs will become an indispensable component of the transition. The distributed nature of DERs allows for localized generation, reduced transmission losses and efficient utilization of renewable resources. DERs empower consumers to actively engage in the energy market, fostering a sense of energy independence and environmental stewardship. To that end, Federal Energy Regulatory Commission (FERC) Order 2222 will soon require the integration of DERs of greater than 100 KW into the electric distribution system.

Increasing deployment of DERs, such as solar panels, micro-turbines, fuel cells, electric vehicles (EV'S) and mobile and stationary energy storage systems, is creating new technical challenges to the centralized legacy electric grid. FERC Order 2222 focuses on the removal of market barriers for DERs and allowing DER participation in wholesale energy markets. The Order promotes the development and use of transactive energy platforms that facilitate the exchange of energy and services between DERs, consumers, and grid operators.

The electric distribution system plays a critical role in delivering safe, affordable, reliable, resilient and clean electricity to consumers. Understanding and applying FERC 2222 in the next few years will help the industry learn how to implement and achieve real zero by 2050.


Wind energy from this Montana billboard is a distributed energy resource (DER)

## Net Zero Energy Buildings

Commercial buildings consume 40% of energy and emit 40% of all carbon dioxide in America. FERC 2222 and net zero buildings can help us start to achieve our environmental goals and provide unique and valuable new business opportunities at the same time. Net zero can be defined several ways. The best definition for early applications is “the net energy used for an asset over the course of a one-year period is produced on site.” Buildings, facilities and plants experience peak periods of energy and water use as temperature, humidity, consumer use and production levels vary. During these peak periods, the facility will need to be connected to the real zero grid of the local electric utility. Early application of net zero concepts to buildings and FERC Order 2222 will help the industry move towards our 2050 real zero goals.

The zero carbon ECO District by Avista in Spokane is leading the way in net zero design

## Conclusion

Utility companies operate in a rapidly evolving industry that faces technological advancements, changing customer demands, and regulatory shifts. Real zero energy has huge implications for the electric T&D industry. Executives, planners and technical teams constantly look for innovative solutions that embrace new technologies, ideas, and approaches to enhance and continuously improve their operations, efficiency, and services to customers. The assumptions and ideas herein are an attempt to help the industry move forward and “solve for” the challenges of achieving real zero energy and the T&D grid to deliver it by 2050.

## About Mike Beehler

Mike Beehler & Associates, LLC offers the "Power of Experience™". We believe that strategically positioning for success and growth in the electric utility industry will require clear vision supported by entrepreneurial creativity, intellectual genius and the very best from other industries.

A New Paradigm of Thinking℠ about safety, reliability, resiliency, affordability, sustainability, compliance, cyber security, our employees.... and the customer.

Mike started his career designing and building transmission lines and substations for Tucson Electric Power and the Hawaiian Electric Company and then spent over twenty years designing T&D infrastructure and consulting on emerging trends at Burns & McDonnell, a large, international architectural/engineering/construction firm. He has written, presented and consulted on reliability centered maintenance, critical infrastructure protection, and program management. In addition, he is a well-known industry writer and speaker on the early definition of the smart grid, 3D/BIM applications in T&D, and development plans for smart cities. Most recently, he is sought for his strategic leadership and vision on the application of emerging technologies in changing business models to include the integration of distributed energy resources, augmented/virtual reality and artificial intelligence.

Mike is a registered Professional Engineer in AZ, FL, HI, TX, CO, KS, GA and AL, a Fellow in the American Society of Civil Engineers and a Member in IEEE and CIGRE. He has been married for over 40 years, and has four adult children and some delightful grandchildren.

If you'd like to chat about the future, please send Mike an email at mebeehler@protonmail.com.

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