National Fuel Cell Research Center
Comments on the June 8 – 10, 2021 Public Workshop Series to Commence Development of the 2022 Scoping Plan Update to Achieve Carbon Neutrality by 2045.

I. Introduction

The National Fuel Cell Research Center (NFCRC) submits these comments on the June 8 through June 10, 2021 Public Workshop Series to Commence Development of the 2022 Scoping Plan Update to Achieve Carbon Neutrality by 2045. The NFCRC would like to affirm and emphasize the importance of recognizing hydrogen and fuel cell systems as required resources in the California Air Resources Board's (CARB) strategy for a decarbonized future. We appreciate the interagency coordination to ensure synergy not only across sectors, but also between strategies and programs.

The National Fuel Cell Research Center facilitates and accelerates the development and deployment of fuel cell technology and systems; promotes strategic alliances to address the market challenges associated with the installation and integration of fuel cell systems; and educates and develops resources for the decarbonization of power and energy storage sectors. The NFCRC was established in 1998 at the University of California, Irvine by the U.S. Department of Energy and the California Energy Commission in order to develop advanced sources of power generation, transportation and fuels and has overseen and reviewed thousands of commercial fuel cell applications.

II. Comments

Stationary fuel cell systems are uniquely suited for providing clean, high-efficiency, 24/7 power generation with virtually zero greenhouse gas (GHG) and criteria air pollutant emissions, and net zero water use. Combustion-based power generation today meets the majority of electricity demand but creates associated emissions of GHG and criteria pollutants and comprises efficiencies that are limited by heat engine constraints. Fuel cells reduce GHG emissions compared to the current grid (with a mix of renewables and combustion-based generation) and emit virtually zero criteria pollutants.[1] They are fuel flexible and operate on hydrogen, natural gas or directed and locally sourced biogas, producing renewable power today.

Fuel cell systems are distributed energy resources (DER) that deliver reliable, scalable, and firm power and heat at customer sites and for utilities on the grid. Sectors such as data centers and telecommunications have already begun to transition to the use of fuel cell systems to replace diesel generators. Significant reductions in GHG emissions are achieved with fuel cell systems through:

1. The combination of high efficiency and extremely high capacity factor results in the displacement of more GHG emissions than equivalent nameplate-sized intermittent resources. Note that the most significant previous GHG and criteria air pollutant

[1] *SGIP 2016-2017 Self-Generation Incentive Program Impact Evaluation Report.* Submitted by Itron to Pacific Gas & Electric Company and the SGIP Working Group, September 28, 2018. Available at: https://www.cpuc.ca.gov/General.aspx?id=7890

reductions achieved in the California Self-Generation Incentive Program were made by fuel cells operating on natural gas.[2]

2. Fuel cells are an integral part of a resilient, always-on energy system and are capable of islanding to serve critical loads in the event of a grid outage, eliminating the need for backup diesel generators and their emissions.
3. Unlike combustion technologies, stationary fuel cell systems are also a scalable resource with global project sizes ranging from under 1 kW to 59 MW operating on biogas, hydrogen and natural gas. As a result, fuel cells do not represent a long-term commitment to fossil fuels and will facilitate a seamless transition to renewable fuels.

A. Fuel Cell Systems Improve Air Quality in Local and Vulnerable Communities

Many comments were made at the June 24 California Air Resources Board meeting about implementing tactical measures to aid vulnerable communities in their access to clean and affordable energy, and the elimination of their exposure to air pollution. Any analysis and calculations included in Scoping Plan update must include the potential reductions and impacts of criteria air pollutants and air toxics and should identify real pathways for reduction. In addition, access of vulnerable populations and disadvantaged communities to clean and affordable energy should be included in the analyses. The positive impacts of the use of non-combustion fuel cell systems in place of combustion diesel generators should absolutely be modeled in this work and addressed in the Scoping Plan. Other agencies have continued to permit the widespread use of small- and large-scale diesel generators, both behind the meter and in front of the meter. The Scoping Plan must provide a guide to reduce and eliminate the use of diesel generators as soon as possible with supporting policy and programs. The societal costs of these diesel generators must be included in the analyses for a just comparison with low- and zero-emission DER and potential impacts, especially in disproportionately impacted or disadvantaged communities.

DER that emit criteria air pollutants have the potential to introduce new sources of emissions into urban airsheds with large populations and thereby cause risks to human health. Many areas of California currently suffer from poor air quality and face major challenges in achieving clean air for the many citizens that live and work within these areas. This is particularly true for communities that are disproportionately burdened by local air pollution. DER such as fuel cell systems that provide clean, efficient energy conversion without combustion also produce a wide range of energy, environmental, and economic benefits for many different industries and applications. Fuel cell systems should be preferentially adopted because of these significant value streams that they provide to communities and to the State. Policies that waive air emission permits for fuel cells have existed for over a decade in California in recognition of the superior air quality co-benefits of fuel cell systems.

California has recently (and very disappointingly) supported the use of diesel generators, rather than support the use of cleaner, commercially available fuel cell electric generation and backup

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[2] *SGIP 2016-2017 Self-Generation Incentive Program Impact Evaluation Report.* Submitted by Itron to Pacific Gas & Electric Company and the SGIP Working Group, September 28, 2018. Available at: https://www.cpuc.ca.gov/General.aspx?id=7890

power systems. Again, these systems do not require permits which expedites the siting and installation of these systems, but, which also has technically excluded them from being more widely adopted because they are not considered best available control technology (BACT) in the current regulatory framework. The California Public Utilities Commission (CPUC) recent recommendations to use diesel generators for resilient power in the face of de-energization events has created a significant air pollution problem with corresponding negative environmental, health, and safety impacts that are caused by all such diesel generators.[3] Since hundreds of megawatts of diesel generators are being deployed for temporary generation at substations, the emissions and health impacts of these diesel generators is tremendous. It is important that the Scoping Plan reflect a path for interagency cooperation to encourage the use of cleaner backup and primary stationary generation before supporting large-scale polluting combustion generation. The NFCRC urges CARB to include immediate recommendations for the use of clean generation alternatives to backup diesel generators, as newly procured diesel generators will be used for the next twenty years or more.

The NFCRC recommends that CARB prioritize addressing local air quality impacts, in addition to GHG reduction benefits of alternative energy resources. Fuel cells are uniquely qualified to serve 24-7-365 power generation as well as backup generation requirements. Due to high operating efficiency (even at the distributed scale) and continuous operation, non-combustion fuel cell systems generate electricity that is cleaner than the utility grid network—resulting in reduced GHG emissions, as proven by substantial data from many jurisdictions and particularly in CPUC reports from the Self-Generation Incentive Program.

A 2018 UC Irvine Advanced Power and Energy Program assessment[4] showed that stationary fuel cell systems can achieve greenhouse gas and air quality co-benefits, which is an essential capability for technology choice within the pursuit of environmental quality goals. This assessment resulted in the following conclusions:

- By off-setting emissions from combustion technologies, fuel cell systems are ideally suited to balance intermittent wind and solar power on the grid while maximizing the GHG and air quality co-benefits of renewable energy.
- The use of fuel cell systems yields improvements in both ozone and $PM_{2.5}$ concentrations in key areas of California associated with high populations and unhealthy levels of pollution including the South Coast Air Basin, San Francisco Bay Area, and Central San Joaquin Valley.
- The integration of combined heat and power (“CHP”) can enhance the air quality and GHG benefits of fuel cells by providing an effective and efficient mechanism to reduce

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[3] Potential Public Health Costs From Air Quality Degradation During Grid Disruption Events, McKinnon et al. http://www.apep.uci.edu/PDF/Potential_Public_Health_Costs_from_Air_Quality_Degradation_During_Grid_Disruption_Events_070921.pdf

[4] *Air Quality and GHG Emission Impacts of Stationary Fuel Cell Systems,* An Assessment Produced by the Advanced Power and Energy Program at the University of California, Irvine, March 2018, available at: http://www.apep.uci.edu/Research/whitePapers/PDF/AQ_Benefits_Of_Stationary_Fuel_Cells_BenMAP_Final_041718.pdf

emissions from traditional thermal generation methods (e.g., industrial boilers and process heat, commercial space and water heating).

- Reductions in pollutant emissions, notably of NOx, achieves improvements in ground level ozone and $PM_{2.5}$ in both summer and winter.
- The economic value of avoided health impacts from air quality improvements is significant and estimated here to be $2,145,950 for a summer day and $1,572,330 for a winter day.

With respect to backup power, fuel cell resiliency has been demonstrated during hundreds of real-world natural disaster and grid interruption events for communities, commercial and industrial energy consumers. To wit, over 60 fuel cell systems have maintained power to telecommunication sites during widespread outages caused by Superstorm Sandy in the Northeast and the Bahamas in 2012.[5] Fuel cells have been installed on the utility side of the meter to ride through outages in Connecticut, Delaware, and Long Island. Millions of customers lost power in the four storms that buffeted the East Coast from March 2-22 in 2018, including those served by the electric grid in the vicinity of nine fuel cell microgrid sites. Despite the combined 26 electric utility outages, the nine fuel cell microgrids in this region maintained power throughout all of these grid outage events.

Other fuel cell systems in the Northeast have powered critical communications and emergency shelters in the aftermath of these storms. Fuel cells have also supplied critical load power to a healthcare facility during triple-digit temperature heat waves that triggered outages for 57,000 customers in Southern California in 2018. Additionally, fuel cells withstood the 6.0 magnitude Napa earthquake in 2014, the Sonoma fires in 2018 and the July 2019 Ridgecrest earthquake, continuously providing power and essential services to customers through all of these utility grid network outage circumstances. During the July 2019 blackout in New York and New Jersey, Home Depot stores across New York state maintained power throughout with stationary fuel cell based microgrids.[6]

Commercial fuel cell systems are available on the market and have been deployed for utility backup power, government communication networks, and telecommunications applications that scale from below 1kW to multi-MW capacities for nearly two decades. There are more than 5,000 telecommunication and cable network facility locations using fuel cell systems for backup power in North America, hundreds of which are in California serving power requirements ranging from under 200 Watts to over 10kW in urban, rural, and remote settings. Fuel cell systems have provided backup power to telecommunications sites during natural disasters like hurricanes in the Southeastern U.S. and the Caribbean, and in California after earthquakes and wildfires. During Tropical Storm Alfred in 2011 and Hurricane Sandy in 2012, fuel cell systems

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[5] Fuel Cell and Hydrogen Energy Association, *Enhancing the Role of Fuel Cells for Northeast Grid Resiliency*, February 2015, available at: https://static1.squarespace.com/static/53ab1feee4b0bef0179a1563/t/54e5e838e4b0072e73714e4b/1424353336299/Northeast-Resiliency-White-Paper-February-2015.pdf

[6] https://www.bloomenergy.com/blog/fuel-cell-powered-microgrids-keep-home-depot-stores-open-through-new-york-power-outages

were instrumental in providing backup power for cell towers and keeping cell phone communications open for many in New York, New Jersey and Connecticut.[7]

Fuel cell systems that can run on stored hydrogen—scalable to the required runtime—have been commercially deployed since the early 2000s. Other fuel cell systems that are used for cell tower backup power can run on a mixture of methanol/water fuel, which can reduce total system footprint for extended runtime (beyond 72 hours). Higher power fuel cell systems (200 kW and larger) that use biogas or natural gas for both continuous and backup power are also being used today by telecommunications providers such as AT&T,[8] Cox,[9] and Verizon.[10] These systems are grid-connected and seamlessly take over the load during a grid outage. These systems have operated for weeks at a time during extended outages in the Northeast and continue to operate as long as fuel is reliably delivered in underground pipeline infrastructure or is locally available.

In the event of a grid outage, the Doosan fuel cell system is capable of an immediate transition to full grid independent power.[11] Plug Power hydrogen PEM fuel cell systems are designed to start in the same amount of time as the current diesel generators that they are currently replacing.[12]

Forty (40) data centers in the U.S. are using Bloom Energy fuel cell systems, including those at eBay, AT&T, Equinix, Apple, and JP Morgan.[13] Each component in the Bloom Energy Server architecture is built with native redundancy of the component, which assures 99% uptime.[14] eBay installed six (6) MW of Bloom Energy fuel cell systems to provide primary, onsite, reliable power matched to the operational requirements of one of their data centers and to meet their sustainability requirements. The system provides 100% of the site electricity demand while drastically reducing carbon footprint with a redundant, modular architecture. This system architecture replaces large and expensive backup diesel generators and UPS components. During a 2015 grid outage, eBay reported that a utility fault dropped the 138,000V utility grid connection while the fuel cell systems worked flawlessly with no impact to their power supply.[15]

Fuel Cell Systems Decarbonize Electric Generation and are Essential for a 100% Renewable Grid

With a substantial deployment of intermittent and diurnal varying renewables with relatively low capacity factor power generation, California is experiencing challenging grid stability issues and gaps in power generation. The use of short-duration energy storage technologies (mostly lithium-

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[7] U.S. Department of Energy, *Calling All Fuel Cells*, December 7, 2012. Available at: https://www.energy.gov/articles/calling-all-fuel-cells

[8] AT&T Progress Toward our 2020/2025 Goals, at 4. Available at: https://about.att.com/content/dam/csr/sustainability-reporting/PDF/2017/ATT-Goals.pdf

[9] Doosan Fuel Cell America Project Profile: Cox Communications. Available at: http://www.doosanfuelcellamerica.com/en/news-resources/project-profiles/

[10] GreenTech Media, Verizon's $100M Fuel Cell and Solar Power Play, April 30, 2013. Available at: https://www.greentechmedia.com/articles/read/verizons-100m-fuel-cell-and-solar-power-play

[11] Available at: electric-load-following-capability-of-the-purecell-model-400_en.pdf (doosanfuelcellamerica.com)

[12] Available at: GenSure Hydrogen Fuel Cell Backup Power - Plug Power

[13] Available at: https://resources.bloomenergy.com/data-centers

[14] Id.

[15] Available at: http://casfcc.org/PDF/Fuel_Cells_For_Resilience_And_Decarbonization_In_California_050120.pdf

ion battery systems) can address some of these gaps, but to-date such implementation has resulted in increased emissions on the California grid.[16, 17] Some of these emissions increases can be eliminated with better rate design and enforcement, which should be pursued. Reversible fuel cells or electrolyzers should also be considered, especially for large magnitude and long duration energy storage because they can also serve as controllable loads that correspondingly help the grid manage instances of overproduction from renewable resources to produce a renewable hydrogen fuel for energy storage and later electricity production or for electrification of transportation via fuel cell vehicles. While battery energy storage is necessary, the inclusion of clean, 24/7 load-following generation is also required for a successful conversion to 100% clean energy.[18] Fuel cells and hydrogen are perfectly suited to serve these roles, and are the most cost effective means for storing massive amounts of electricity for long durations due to separate power and energy scaling.

Benefits of fuel cell systems include the provision of 24/7, clean, load-following power at close to 100% capacity factors. Importantly, this high capacity factor corresponds to the production of clean, renewable electric energy (MWh) per unit of power capacity (MW) that is on the order of six (6) times that of solar power systems (assuming a 15% capacity factor for solar) and on the order of three (3) times that of wind power systems (assuming a capacity factor of 30% for wind). Thus, investments in fuel cell capacity produce vastly more renewable energy than wind or solar power systems per unit of capacity installed. This translates into substantially more GHG reductions per MW installed. Unlike investments in solar and wind power systems, installations of fuel cell systems can be used by the utility to (1) support local capacity and spinning reserve requirements that are used for grid reliability, and (2) serve as an alternative to costly utility system transmission and distribution upgrades to this system. In addition, the energy density of fuel cell systems significantly reduces the land footprint required for onsite generation. Typically only one acre is required for one MW of generation, allowing for operation of clean power generation in high density areas and increased acreage available for habitat restoration and preservation in dense urban environments.

In addition, any urban environment that desires to achieve full decarbonization must interact with the electric and natural gas grids to produce off-site power (mostly from remote sun and wind resources) and must store and transport renewable power and renewable fuel. Complete decarbonization of any dense urban environment requires significant investments outside of the urban environment and significant investments in storage, transmission and distribution. The fact that insufficient space and insufficient renewable resources are available in any dense urban environment to meet all of the energy demands (stationary power and transportation) is a situation that is replicated in every urban environment around the world. No urban environment has enough roof-top, building-envelope, or ground-mounted solar space to meet all of the urban environment energy demands. Solutions that scale for complete decarbonization of any urban environment require investment in off-site renewable energy that must be produced remotely (e.g., in desert or wind corridors) and then stored and delivered to the urban environment in

[16] Id.
[17] MQRI– California ISO, Greenhouse Gas Emission Tracking Report, February, 2018. Available on-line at: https://www.caiso.com/Documents/GreenhouseGasEmissions-TrackingReport-Feb2018.pdf
[18] Davis, *et. al., Net-Zero Emissions Energy Systems,* Science **360**, 1419 (2018) 29 June 2018

either wires or pipes. And delivering such renewable energy in both pipes and wires is always the most resilient and most cost effective solution.

CARB must include the use of load-following, non-combustion fuel cell systems for general grid support and to increase reliability and resiliency in the analyses and modeling for the Scoping Plan Update. Utility-scale procurements of fuel cell systems can provide unique co-benefits. Fuel cell systems are deployed today on the utility-side of the meter to create grid support solutions where transmission or distribution infrastructure or clean, 24/7, load-following power generation to complement the increasing deployment of intermittent solar and wind resources, and to support grid reliability in locations where it is most needed – including disadvantaged communities.

Fuel cell systems support the utility grid network and can also provide ancillary services such as:

1. Peak demand reduction;
2. Power quality;
3. Grid frequency and voltage support;
4. Capacity and spinning reserve;
5. Avoidance of expensive transmission and distribution system upgrades; and
6. Fast ramping and load-following.

The installation and operation of fuel cell systems in a highly dynamic utility grid network environment: 1) directly complements intermittent renewable power generation, 2) improves the reliability and stability of a grid utilizing a high penetration of renewable power generation, and 3) causes no challenging need for increasing storage or other grid infrastructure.

A modern grid and utility infrastructure incorporates resiliency and microgrids into energy planning. When paired with storage, wind, solar, demand response, and other technologies, fuel cell systems can serve as the backbone for microgrids that integrate numerous distributed energy resources and controls. Microgrids that use fuel cell systems as baseload power can immediately disconnect from the grid and island (operate autonomously) from the larger grid when circumstances demand (e.g., grid outage). The fuel cell installation innately operates as an energy management system, with critical loads for backup power already identified and immediately followed in the event of an outage. A fuel cell system can smoothly transition from the grid to fully power the load during a grid outage, without interruption to the end user, and to seamlessly re-connect to the grid when its power is restored. Fuel cells can be, but do not need to be, connected to a storage device to provide these and other resiliency benefits.

Stationary fuel cell systems offer a means to improve resiliency by not only providing continuous local clean power and thermal energy, but also to seamlessly transition to islanding operation to serve dedicated loads. This resilient operation replaces both diesel backup generators as well as other dirtier 24-7-365 power generation technologies on the grid with the same installation. This type of resilient fuel cell operation has occurred through hurricanes, super storms, earthquakes, fires and other grid outage events in the Northeast and around the world.

There are many valid methods for quantifying the benefits of resiliency that should be considered by CARB in the Scoping Plan. Industrial Economics, Incorporated (IEc) comprehensively calculated the resiliency benefits derived from the partnership between the New York State Energy Research and Development Authority (NYSERDA) and the Governor's Office of Storm Recovery to improve electric system performance and resilience.[19] Specifically, IEc utilized a robust, publicly available approach to estimate the resiliency benefits of a specific microgrid that included:

- NREL's Interruption Cost Model to estimate the cost of outages to C&I customers;
- FEMA's Benefit-Cost Analysis to estimate the costs of degraded fire, police, and emergency services as a proxy for value of lives saved during a power interruption; and
- IMPLAN to estimate the regional economic costs of an outage, including damage to local infrastructure, lost productivity, and reduced wages.

This analysis revealed that, assuming just seven hours of interruption annually, the 20-year net present value of the microgrid configuration analyzed by IEc was estimated at $22.4 million, including the value of healthcare services—such as interruption impacts on survival probability—that would otherwise have been diminished without the microgrid and operational savings from displaced diesel generators. Additionally, the analysis found that a one-day power interruption would result in $5 million in lost sales, $3.1 million in lost regional GDP, and lost wages equivalent to over 32 jobs.[20]

CARB should consider the Brooklyn Queens Demand Management Demand Response Program that allows ConEdison to plan for and maintain their electric grid infrastructure, while supplying reliable energy during peak periods of high demand.[21]

Fuel cell companies have installed multiple projects as part of this program. The program ultimately avoided nearly $1 billion in ratepayer costs through the use of targeted DER installations. The program projects in Brooklyn, New York included one project that uses solar PV, storage, and fuel cell technologies together at a low-income housing development, to optimize the efficiency, reliability, and affordability of the project, with the added benefit of avoiding the use of diesel generators in an area that experiences increasing blackouts.

With respect to land use:

- In Korea, Doosan has installed 30.8 MW of fuel cells for district heating and electricity for 71,500 homes in the City of Busan. This system can also operate when the grid goes down

[19] https://pubs.naruc.org/pub/531AD059-9CC0-BAF6-127B-99BCB5F02198

[20] National Association of Regulatory Utility Commissioners, "*The Value of Resiliency for Distributed Energy Resources: An Overview of Current Analytical Practices*," April, 2019.

[21] Brooklyn Queens Demand Management Demand Response Program Overview, available at: https://www.coned.com/en/business-partners/business-opportunities/brooklyn-queens-demand-management-demand-response-program

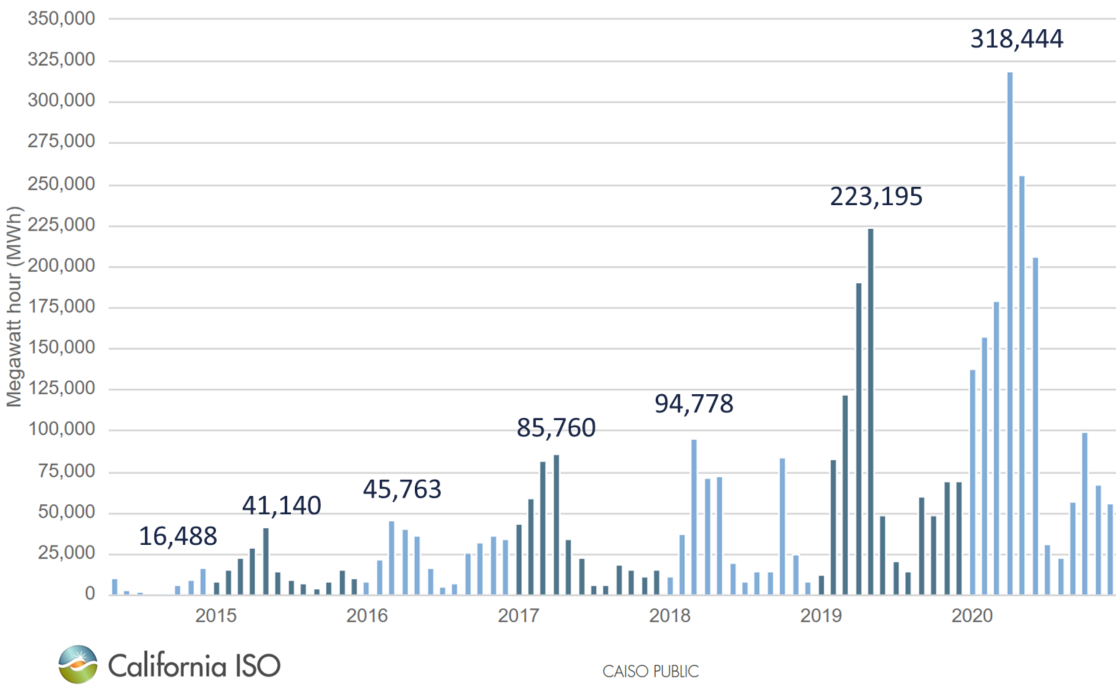
and is configured in a tiered structure and sited on only one acre of land; an equivalent 30 MW solar farm could require more than 75 acres and would produce as little as 1/6th the amount of electric energy and zero heat.

- Plug Power has over 90 installations using stored liquid hydrogen for material handling customers that consume over 24 tons of hydrogen daily. This same type of distribution and storage system will be used in future data center applications. Further, while the actual footprint of the diesel engines alone may be smaller than the footprint of the equivalent power of fuel cell systems, additional space is required for diesel fuel storage. Even if the diesel fuel is stored underground, nothing can be stored above the underground diesel tanks, necessitating additional footprint.

Directed by Senate Bill (SB) 1339, enacted in 2018, the California Public Utilities Commission (CPUC) is currently conducting a proceeding in consultation with the California Energy Commission and California Independent System Operator, to undertake a number of activities to further develop policies related to microgrids. The CPUC voted to initiate a new rulemaking to consider how to implement the requirements of SB 1339 at its September 12, 2019 public meeting. The "Order Instituting Rulemaking" (OIR) that formally launched the new proceeding was then officially issued on September 19, 2019. The OIR includes a preliminary description of the issues that the Commission intends to address in the rulemaking. To-date, however, multi-technology microgrids like those implemented in all of the jurisdictions noted above (e.g., for microgrids that include PV, storage, and both behind the meter and in front of the meter fuel cell systems) have not received a framework for their broad adoption to create the significant set of benefits noted above for local communities. In particular, CARB should encourage and support the development of such microgrid policies in California by objective analyses of the considerable environmental and grid-support benefits that stationary fuel cell systems and hydrogen use in microgrids can deliver.

The Transition to Hydrogen in the Gas System is Facilitated by Fuel Cell Systems

Over-generation and curtailment of renewable power is already occurring in California due to an excess of solar and wind power that grid operators are unable to admit into the system during many times throughout the year, and especially in Spring. The figure below shows data for renewable power curtailments in the California Independent System Operator (CAISO) system alone. Notice that the curtailments are substantially increasing every year since they began to become tracked in 2014 with more than 318,000 MWh of curtailed renewable electricity wasted in April of 2020 alone.



The fact that the curtailed energy from newly installed renewable power generation sites is no longer being compensated for in power purchase agreements is leading to a major decline in renewable power systems development in California at exactly the time when the pace of renewable power generation installations must increase if we are to meet our 2045 zero emissions goals. Note that the study and presentation from E3 in a Fall 2020 CARB workshop identified this market challenge and the need to address increasing curtailment to encourage more rapid development and installation of renewable power generation throughout the state.

While some amount of renewable power system overbuild and curtailment is usually present in optimized plans for achieving 100% zero emissions goals, the pace at which curtailment is increasing in California is not sustainable. There is a very significant need for additional flexible load and energy storage to complement the need to more rapidly adopt new renewable generation. The largest resources for flexible load and storage of massive amounts of renewable energy in the state of California are those associated with the gas systems of San Diego Gas and Electric, Southern California Gas, and Pacific Gas and Electric. CARB should include the study of gas system transformation and its potential impacts for achieving a 100% zero emissions economy in the Scoping Plan analyses.

Eventually all of the fossil content in the gas system must be eliminated, but, any well-meaning but overly broad ban on gas system investments would only preclude the ability to transform the system to distribute renewable hydrogen and biogas in the future. At the same time, divesting in the gas system instead of investing in its transformation will prevent immediate emission reductions from technologies such as combined heat and power, fuel cells, and microgrids, all of which help displace central station power plants and lower greenhouse gas and pollutant emissions while simultaneously eliminating the need for dirty diesel backup generators.

Natural gas use, particularly for electricity generation, has increased in recent years due to enhanced resource availability from non-traditional reserves and pressure to reduce GHG from higher-emitting sources, including coal generation. Natural gas power generation can play an important role in supporting renewable resource integration by (1) providing essential load balancing services, and (2) supporting the use of gaseous renewable fuels through the existing infrastructure of the natural gas system. Additionally, advanced technologies and strategies including fuel cells and combined cooling, heat and power (CCHP) systems can facilitate natural gas and renewable gas generation with low emissions and high efficiencies. A 2018 UC Irvine paper reviews the literature regarding emissions from natural gas energy conversion with a focus on power generation which includes analyses and discussion in the context of GHG and air quality impacts. [22] In addition to enabling high adoption of renewable electricity today, a pathway forward is proposed for natural gas infrastructure transformation over time to maximize environmental benefits and support renewable resources in the eventual attainment of 100% zero emissions.

It is not the infrastructure that determines the resulting environmental benefits or harm – it is the use of that infrastructure that determines the impacts. As CARB updates the plan to develop the most feasible pathways to decarbonization and improve air quality, the NFCRC recommends an analysis to support understanding which future energy systems can meet electricity and thermal energy demands to achieve zero emission goals in all sectors of the economy. Natural gas power generation is currently, and renewable gas (e.g., hydrogen) will become in the future, the most important dispatchable resource that supports the integration of renewable resources on the grid by 1) supporting the use of renewable gaseous fuels in the existing gas infrastructure,[23] 2) providing critical load balancing services to the grid,[24,25] and 3) producing a resilient and reliable system for energy conversion and delivery to end uses. When generation strategies include combined cooling, heat and power (CCHP) systems like fuel cells, they facilitate the lowest emission, most efficient, and most resilient gas generation available today.

Electrolysis, allows localities to convert otherwise curtailed solar and wind power and cheap renewable power whenever it is available to hydrogen, [26] allowing it to be stored

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[22] Mac Kinnon, M., Brouwer, J. and Samuelsen, S., *The role of natural gas and its infrastructure in mitigating greenhouse gas emissions, improving regional air quality, and renewable resource integration*, *Progress in Energy and Combustion Science*, 64 (2018) 62 – 92.

[23] Han J., Mintz M., Wang M., Waste-to-wheel analysis of anaerobic-digestion-based renewable natural gas pathways with the GREET model. Argonne National Laboratory(ANL);2011.ANL/ESD/11-6. Available at: http://www.osti.gov/bridge/purl.cover.jsp?purl=/1036091/.

[24] Shaffer B., Tarroja, B., Samuelsen S. *Dispatch of fuel cells as transmission integrated grid energy resources to support renewables and reduce emissions.* Applied Energy 2015;148:178–86.

[25] Jury C., Benetto E., Koster D., Schmitt B., Jl Welfring. *Life Cycle Assessment of bio-gas production by mono-fermentation of energy crops and injection into the natural gas grid.* Biomass Bioenergy 2010;34:54–66.

[26] Parra D, Zhang X, Bauer C, Patel MK: *An integrated techno-economic and life cycle environmental assessment of power-to-gas systems*. *Appl Energy* 2017, **193** :440–454. https:// doi.org/ 10.1016/ japenergy.2017.02.063.

indefinitely and later delivered to homes and businesses via the very same highly resilient infrastructure that is currently used to deliver natural gas.[27] The NFCRC recommends that the Scoping Plan Update address the development of means to store excess energy for later use, using power-to-gas technologies currently being pioneered by countries such as Australia,[28] France,[29] Germany,[30] the Netherlands[31] and the United Kingdom.[32,33,34]

To enable the use of the existing gas infrastructure for decarbonized hydrogen, the NFCRC recommends that the Scoping Plan address the following:

1. Economics of alternatives for 100% decarbonized grid considering:
    - Magnitude and dynamics of all stationary and transportation energy demand
    - Magnitude of storage resources required to reliably meet such demand throughout the year with 100% renewable power
    - Cost and resiliency of transforming all demand to electricity and using only electric infrastructure and electricity storage technologies to achieve 100% renewable energy in the state
    - Cost and resiliency of transforming many loads to electricity and using both the gas and electric infrastructures for storing, transmitting and distributing 100% renewable energy in the state
    - Cost of engendering resiliency in the context of increased wildfires and public safety power shutoff (PSPS) events

2. Recognition of the safety attributes and concerns of hydrogen which include the following characteristics that should be evaluated and addressed to enable ubiquitous consumer use and contact with renewable hydrogen
    - Broadest flammability limits
    - Low ignition energy (at stoichiometric)
    - Highest diffusivity
    - Lowest density
    - Low total energy per unit volume
    - Multiple types of accident and leak circumstances

3. Enable hydrogen injection into the existing natural gas infrastructure to provide an immediate and massive renewable power off-take for addressing curtailment and encouraging massive renewable power systems development in the state.

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[27] Saeedmanesh, A., Mac Kinnon, M. and Brouwer, J. *Hydrogen is Essential for Sustainability,* Current Opinion in Electrochemistry 2018, 12:166–181.
[28] https://arena.gov.au/news/hydrogen-to-be-trialled-in-nsw-gas-networks/
[29] https://fuelcellsworks.com/news/french-minister-unveiled-his-100m-hydrogen-plan/
[30] https://www.dena.de/en/topics-projects/projects/energy-systems/power-to-gas-strategy-platform/
[31] https://www.mhps.com/news/20180308.html
[32] https://networks.online/gphsn/news/1000904/trial-explore-blending-hydrogen-gas-network
[33] *Id.*
[34] https://www.telegraph.co.uk/business/2018/01/06/hydrogen/

- Even small percentages of hydrogen injection into the natural gas system (e.g., 5-10% by volume) could provide a massive resource for supporting very high renewable use in the electric grid.
- Investigate challenges to hydrogen injection and conversion throughout the infrastructure by holding hydrogen to and hydrogen natural gas mixtures to standards of gas infrastructure.
- Investigate hydrogen leakage phenomena. A recent study shows that hydrogen may leak at the same rate as natural gas in typical low-pressure gas infrastructure, but much more needs to be done.
- Encourage regulation and policies at CARB and sister agencies to expedite the formulation and adoption of pipeline hydrogen injection standards
- Investigate the subsequent piecewise transformation of gas infrastructure to 100% renewable hydrogen.

4. <u>Manage embrittlement of existing pipelines and other gas infrastructure</u>[35]
A 2019 study of hydrogen embrittlement of line pipe steels in the natural gas transmission and distribution network shows that under typical pressure fluctuations in the natural gas network, cracks with depths less than 40% of the wall thickness will never reach depths equal to 75% of the wall thickness. This is a conservative estimate that results from i) the nature of the geometry of the initial flaw in the ID surface that we used in the analysis, ii) the fact that the existing experimental data for the effect of hydrogen on the Paris law are for pressures that are orders of magnitude larger than the partial pressures intended for the hydrogen gas in the mixture, and iii) the experimental data are for fatigue crack growth in pure hydrogen gas without impurities normally present in natural gas, such as oxygen or methane, that can inhibit hydrogen uptake.

5. <u>Transform massive storage facilities such as salt caverns, saline aquifers, and depleted oil and gas fields</u>
Salt caverns are already widely used and proven and as a storage facility for hydrogen. Results of both daily and seasonal simulation conducted by UC Irvine suggest that with the same size wind farm and salt cavern, a compressed hydrogen energy storage system could better complement the wind intermittency and could also achieve load shifting on a daily and seasonal time scale.[36] Air Liquide and Praxair have been operating salt cavern hydrogen storage in Texas since 2016. These massive energy storage facilities have a very low leakage rate, and represent safe and low cost storage. Europe has had similar success in using salt cavern storage. There is a need to also evaluate the potential to transform saline aquifers and depleted oil and gas fields for hydrogen storage.

[35] Dadfarnia M et al., *Assessment of resistance to fatigue crack growth of natural gas line pipe steels carrying gas mixed with hydrogen*, International Journal of Hydrogen Energy, https://doi.org/10.1016/j.ijhydene.2019.02.216
[36] Maton, J-P., Zhao, L., Brouwer, J., *Dynamic modeling of compressed gas energy storage to complement renewable wind power intermittency,* <u>International Journal of Hydrogen Energy</u> 38 (2013) 7867 e 7880

Magnum Development is bringing together a Western Energy Hub ("WEH") site located adjacent to the Intermountain Power Project ("IPP") in Millard County, Utah, that:

> …can serve as a foundation of the Sustainable City Plan for Los Angeles, Southern California, and the Western region. This regional platform, with ready access to Southern California energy and transportation markets, offers a unique combination of geography, geology, energy and transportation infrastructure, and renewable energy resources that can serve to rapidly deploy new clean energy technologies and practices at commercial scale—meeting regional needs and speeding clean energy adoption and use worldwide... The unique combination of resources and infrastructure makes the WEH site an exceptional platform for the development of a regional clean energy hub serving both power and transportation markets. The potential exists to use the massive and unique salt cavern resource to store wind and solar energy in the forms of hydrogen and compressed air and to access greater Los Angeles energy and transportation markets via a 2,400 MW, 500 kV direct-current transmission line, as well as major rail and highway routes for moving hydrogen to regional transportation markets.[37]

Depleted oil and gas fields in California could also potentially be used for hydrogen storage, if some critical research and development in these areas is completed:

- H2 leakage
- H2 reaction with petroleum remnants
- H2 biological interactions
- H2 storage capacity
- H2 safety

Finally, the NFCRC supports the eventual elimination of natural gas use as the gas infrastructure is transformed over time to increasingly use renewable gases and ultimately renewable hydrogen. This renewable hydrogen will emit zero GHG and zero criteria pollutant emissions in its production, transmission and distribution and conversion in fuel cell systems, while enabling higher levels of renewable electricity use in all sectors of the economy. Transition of such a massive and ubiquitous resource (natural gas infrastructure) is REQUIRED for society to meet zero emissions goals in the long-term.

[37] Reed, J., Brouwer, J., Webster, R. *Integrating Clean Energy Technologies with Existing Infrastructure, Western Energy Hub Site Benefits for Rapid Clean Regional Grid Transition*. January 30,2020. Available at: Microsoft Word - White Paper_v11_5.docx (uci.edu)

III. Conclusion

The NFCRC appreciates the opportunity to give input to the 2022 Scoping Plan update, based on the June workshops. The forthcoming update to the AB32 Scoping Plan should include GHG reducing fuel cells, and hydrogen as unique technology solutions that can assist California in achieving its immediate 40% GHG emissions reduction goal and that are essential for achieving 100% zero emissions. The NFCRC will further provide specific recommendations for the expanded role of fuel cell systems and hydrogen in the 2022 Scoping Plan when the draft document is released.

Sincerely,

/s/ Jack Brouwer

Director
National Fuel Cell Research Center
University of California Irvine
Irvine, CA 92697-3550
Tel: 949-824-1999 Ext. 11221
E-mail: jb@nfcrc.uci.edu