National Fuel Cell Research Center
Comments on the August 23 Public Workshop on the Energy Sector to Inform Development of the 2030 Target Scoping Plan Update

I. Introduction

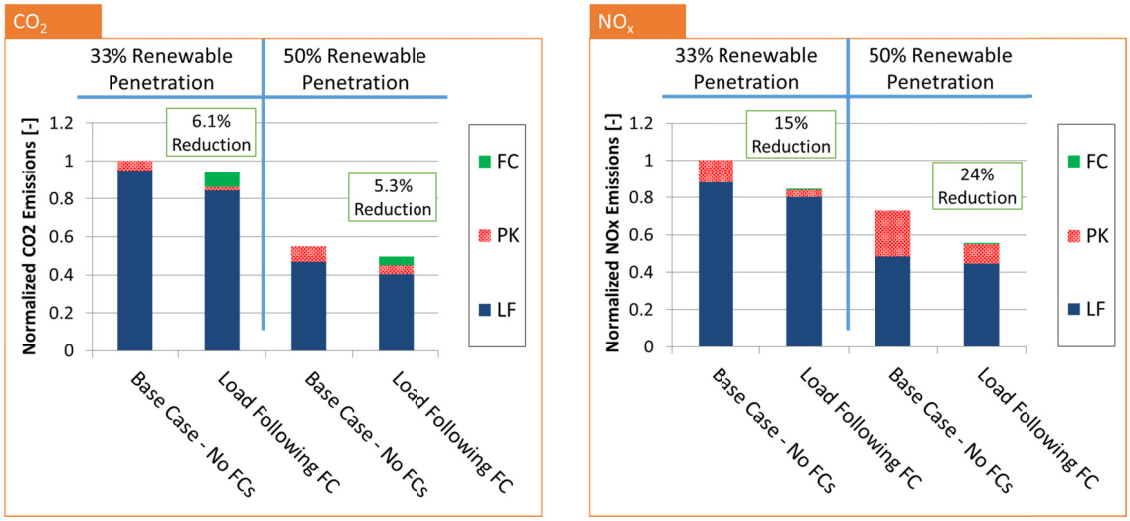
The National Fuel Cell Research Center (NFCRC) submits these comments on the August 23 *Public Workshop on the Energy Sector to Inform Development of the 2030 Target Scoping Plan Update*. The NFCRC would like to affirm and emphasize the importance of recognizing fuel cells as a major and critical resource in the California Air Resources Board's (CARB) strategy for a low-carbon future. We also appreciate the coordination between agencies to ensure synergy not only across sectors, but also between strategies and programs.

The NFCRC facilitates and accelerates the development and deployment of fuel cell 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 distributed generation and combined heat and power (CHP) stakeholders around the world. The NFCRC was established at the University of California Irvine by the U.S. Department of Energy (DOE) and the California Energy Commission (CEC) with the goal of both developing and transitioning to a form of power generation that is both energy efficient and environmentally sensitive. The NFCRC is working with GE-Fuel Cells, LLC; LG Fuel Cell Systems Inc.; Bloom Energy; Doosan Fuel Cell America; and FuelCell Energy.

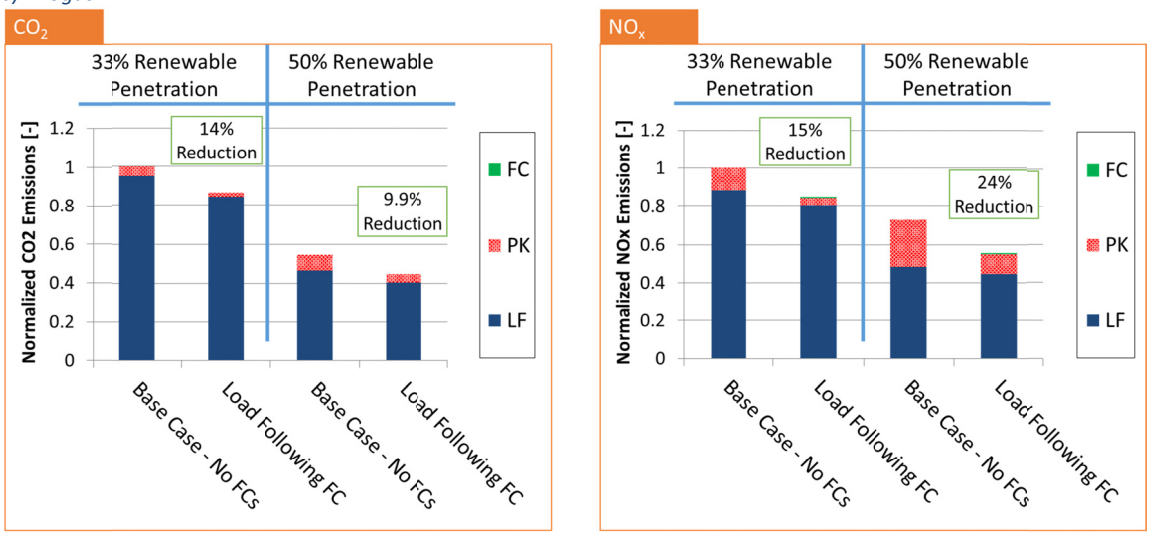
II. Comments

Fuel cells systems address multiple sectors in the AB32 Scoping Plan including water, agriculture, transportation and green buildings and are a direct example of the synergies between sectors that the Scoping Plan addresses. Over 30% of the stationary fuel cells deployed in California are operating as 24/7 renewable sources of power generation, powered by biogas that is either directed or produced local to the generator. The State should be encouraging any and all means by which a renewable fuel can be converted to electricity with ultra-low GHG and virtually zero emission of criteria pollutants, which is the case for all fuel cells operating on either directed or onsite biogas (Figure 1).

a) Natural Gas



b) Biogas



- All results normalized to Base Case at 33% renewable penetration (energy basis)
- LF –Load Following Gas Turbine; PK – Gas Turbine Peaker; FC – Load Following Fuel Cell

Figure 1. Grid Simulation Modeling of 5 GW Biogas Fueled Fuel Cell Deployment in California with Different Renewable Penetrations[1,2]

Figure 1 represents the reduction in both carbon dioxide (CO2) and nitrogen oxides (NOx) by the replacement of 5GW (as an example) of load following gas turbines with load following fuel cells. In the "Base Case," there are no fuel cells. In the "Load Following FCs" case, conventional gas turbine load following generation is replaced by load following (35% turndown, 1 hr minimum up time, and 1 hr maximum down ride through time) and high efficiency (52% peak HHV) fuel cell generation.[3] The stationary fuel cells, presented for two renewable penetration scenarios, reduce both GHG and criteria pollutant emissions by providing grid balancing support that is significantly cleaner and more efficient than conventional balancing technologies. Technologies that can provide highly dynamic grid balancing support are necessary as renewable penetrations increase.

A major additional consideration is the very recent advance in stationary fuel cell technology that is called "tri-generation" where the stationary fuel cell generates hydrogen in addition to electricity and heat. The hydrogen can then be used to supply industrial demands for hydrogen, provide fuel for the transportation sector and fuel cell vehicles, or power a particularly flexible and 100% dispatchable and zero emissions proton exchange membrane fuel cell. When operated on biogas, the hydrogen produced is renewable bio-hydrogen. As a result, biogas powered tri-generation portends a major opportunity to meet the strict California requirement that all hydrogen dispensed for fuel cell vehicles must be at least 33% renewable. Fortuitously, a major market application today in California is the installation of stationary fuel cells at water resource recovery facilities. Stationary fuel cells are fueled by biogas at these facilities, producing 24/7 renewable electricity that is used to power the facility, and heat that is directly used to heat the digester. The provision of a capability to tri-generate and dispense dispatchable hydrogen has been successfully demonstrated at the Orange County Sanitation District.

[1] Shaffer, B., Tarroja, B., & Samuelsen, S. (2015). Dispatch of fuel cells as Transmission Integrated Grid Energy Resources to support renewables and reduce emissions. *Applied Energy*, *148*, 178–186.
[2] Eichman, J. D., Mueller, F., Tarroja, B., Schell, L. S., & Samuelsen, S. (2013). Exploration of the integration of renewable resources into California's electric system using the Holistic Grid Resource Integration and Deployment (HiGRID) tool. *Energy*, *50*, 353–363.
[3] Existing phosphoric acid fuel cell technology today provides this service at the device scale.

Fuel cells in California are a fuel flexible replacement for combustion technology, providing clean, primary, firm (24/7, load-following) power generation. They also provide backup power and hydrogen generation that, when operating on any fuel type (biogas, renewable hydrogen, or natural gas) reduces both greenhouse gas (GHG) and criteria air pollutants compared to the traditional firm combustion-based power generation supporting the grid. Stationary fuel cells are installed as clean, firm primary power generation in California at green and LEED certified buildings such as hospitals, telecommunication sites, hotels, prisons, water resource recovery facilities, food processing plants, universities, office buildings, and server farms. Some applications are all-electric, whereas other applications recover the heat for space heating, cooling, or steam. The use of heat for the production of chilled water is increasing in popularity as an alternative to electric driven vapor compression refrigeration. An example is the generation of 200 tons of chilling at the UCI Medical Center from a 1.4 MW stationary fuel cell. In addition to virtually zero emission of criteria pollutants, regardless of fuel source, fuel cell systems consume net-zero water in the production of energy.

Fuel cells have highly dynamic dispatch capabilities to (1) manage the diurnal variation, constrained capacity factor, and intermittencies associated with solar and wind power generators, and (2) increase the maximum penetration of renewable resources that can be accommodated in the utility grid network. These capabilities will result in additional GHG reductions through the integration of renewables and the ultimate achievement of a 100% renewable grid.

Fuel cells are a GHG reducing technology that can serve both onsite and utility scale generation with negligible criteria air pollutant emissions. They are a critical tool to reduce GHG emissions from the State's energy sector and have a positive, direct public health impact on communities with significant exposure to air pollution. Clean fuel cell power can also be controlled and dispatched in a manner that will increase the market penetration of other non-controllable clean power generation, such as wind and solar power. These attributes are consistent with the mission of the ARB and legislative direction through AB 32. The energy density of fuel cell systems also allows them to significantly reduce the land footprint required for onsite generation.

Fuel cell systems are fuel flexible and can operate on biogas, hydrogen, or natural gas and, utilizing any of these sources, fuel cells reduce both GHG and criteria air pollutant emissions (e.g., NOx). Power generation produced through natural gas combined cycle (NGCC) power plants meets the majority of electricity demand in California today, but with the concomitant emission of criteria pollutants and with efficiencies that are limited by heat engine constraints. Alternative and emerging clean high-efficiency fuel cell systems achieve low emissions of GHG and virtually zero emission of criteria pollutants. When using natural gas, fuel cells reduce both GHG and criteria pollutant emissions compared to generation from the current grid. In addition, fuel cell operation on renewable fuels (e.g., biogas or renewably produced hydrogen) virtually eliminates GHG emissions.

Under the original Scoping Plan and subsequent updates, the ARB has recognized the environmental and energy benefits of fuel cell technologies. This is in part due to the co-benefits achieved by the use of fuel cell systems, which address all of the Principles of California's Climate Strategy.

A. Create Jobs. Fuel cell companies and their supply chains are contributing to U.S. manufacturing, exports, and job growth. The fuel cell industry workforce fills a wide array of jobs in sectors that include R&D, engineering, manufacturing, installation, service, and sales. The industry as a whole has generated thousands of jobs and millions in revenue and investment including state and local tax revenue. In 2014, worldwide fuel cell revenue grew by almost $1 billion, reaching a total of $2.2 billion, up from $1.3 billion in 2013. Significant growth in U.S. revenues was driven

by large-scale stationary fuel cell systems as well as mobile fuel cells for material handling.[4] It has been estimated that widespread adoption of fuel cells could create 180,000 new jobs in the U.S. by 2020.[5]

B. Transform to a Clean Energy Economy. California has long been recognized as a world leader in adopting environmentally sustainable energy sources. In addition to the above economic impact that fuel cell systems create in terms of jobs and growth of the clean energy industry, fuel cells, as a class of high efficiency, non-combustion power generation technologies, are contributing to achieving the state's energy and environmental goals by providing reliable, cost effective, clean power across multiple sectors in the State. In addition, since high efficiency can be achieved at the distributed power generation scale, fuel cell systems offer additional emissions reduction benefits by providing combined cooling, heating and power (CCHP). As of October 2014, more than 100 MW of fuel cells were installed in more than 100 cities in over half of California's 58 counties, representing enough capacity to provide electricity to 100,000 homes.[6]

C. Save Water. While fuel cell systems directly impact the Energy Sector, they also provide a significant water use reduction impact. Fuel cells operate in a water balance, with no consumption or discharge of water in normal operations. To illustrate, the use of a 400kW fuel cell system to generate combined heat and power at a building can save over one million gallons of water in the course of a year, compared to the water required to generate the same amount of electricity at a central power plant.

D. Support Vulnerable Communities. The landscape of power generation is shifting from large central power plants to distributed generation (DG) that efficiently and economically generates electricity and other useful products on-site. Benefits of DG include reducing complexities and costs associated with transmission and distribution of power and providing smoother integration of environmentally beneficial technologies, including renewable resources. However, the DG model also has the potential to introduce new sources of pollutant emissions into urban airsheds with large populations and thereby raising concerns for human health – including in the South Coast Air Basin (SoCAB), and San Joaquin Valley of California[7]. SoCAB currently suffers from poor air quality and faces major challenges in achieving clean air for the many citizens that live and work within its boundaries. This is particularly true for economically disadvantaged communities that are often disproportionately burdened by air pollution. Therefore, DG technologies such as fuel cells that can provide clean, efficient energy conversion in many different industries and applications produce a wide range of energy, environmental, and economic benefits that have significant value to the State.

Due in part to the electrochemistry versus high-temperature combustion chemistry, fuel cells reduce emissions of criteria pollutants and GHGs from traditional combustion-based DG power generation and CCHP energy systems.[8] Demonstrating this, Figure 2 displays the emissions of NOx per kWh for both traditional and advanced DG heat engines and fuel cells operating on natural gas. Fuel cells emit virtually no criteria pollutants including nitrogen oxides (NOx), sulfur

[4] Fuel Cell Technologies Market Report 2014, U.S. Department of Energy Fuel Cell Technologies Office, p 13. (http://energy.gov/sites/prod/files/2015/10/f27/fcto_2014_market_report.pdf)
[5] U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, http://energy.gov/eere/education/explore-careers-hydrogen-and-fuel-cells
[6] http://www.casfcc.org/STATIONARY_FC_MAP/default.aspx
[7] Carreras-Sospedra, M., et al., *Central power generation versus distributed generation-An air quality assessment in the South Coast Air Basin of California*. Atmospheric Environment.
[8] Rubin, E.S., A.B. Rao, and C. Chen. *Comparative assessments of fossil fuel power plants with CO2 capture and storage*. 2005.

oxides (SOx), particulate matter (PM), and carbon monoxide (CO).[9] If the fuel input is hydrogen, only water vapor and nitrogen are emitted. If the fuel is natural gas or another hydrocarbon fuel, then CO_2 and trace amounts of pollutants are also generated. Due to the high electrical efficiency, the amount of CO_2 emitted per kWh of electricity generated is substantially lower than from conventional power generation technologies.[10] The ability of fuel cells to capture and use the high-quality thermal energy further reduces the amount of CO_2 emitted, the ability of fuel cells to operate on biogas results in net zero emission of carbon, and the ability of fuel cells to operate on renewable hydrogen results in zero emission of carbon.

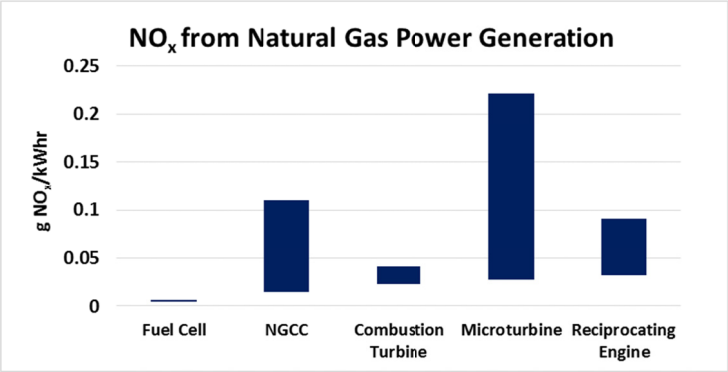


Figure 2: Emissions of NO_x from Natural Gas Power Generation Devices. Data for NGCC [6-8], Data for others [5]

Even while utilizing natural gas, fuel cells can generate clean power (i.e., virtually zero emission of criteria pollutants) at high efficiency that benefits air quality while, at the same time, supporting California's GHG reduction goals under AB 32. This is particularly important for deployment in disadvantaged SoCAB communities since stationary fuel cells can be used to improve the quality of power provision and infrastructure where it is truly needed, while also contributing to cleaner air and improved health of citizens. In fact, fuel cells are suitable for citing near or even inside buildings (due to being virtually zero emitting of pollutants and acoustically benign) and the avoidance of the challenges related to permitting and zoning. These attributes are reflected in the South Coast Air Quality Management District protocol to waive permitting for fuel cells operating on natural gas due to their favorable environmental performance.

E. Give Consumers Clean Energy Choice. To meet the demands of the next-generation grid, stationary fuel cells systems are (1) being developed and deployed with requisite load-following attributes, (2) operate on hydrogen as well as natural gas and biogas, and (3) developed to integrate with a gas turbine engine to create a "hybrid" power generator with remarkably high efficiency. Simply stated, stationary fuel cells are (1) a key resource, along with storage, required to manage and enable a 100% renewable grid, and (2) a perfect match to hydrogen energy storage in providing the ideal means for converting massive amounts of renewable fuel into electricity.

It should also be noted that fuel cell systems can provide clean power and heat with capacity factors that are over 95%. This corresponds to the production of clean renewable electric energy (MWh) per unit of capacity (MW) that is on the order of six (6) times that of solar power systems (assuming a 15% capacity factor) and on the order of three (3) times that of wind power systems (assuming a capacity factor of 30%). Thus investments in fuel cell distributed resource

[9] IEAGHG, *Emissions of substances other than CO2 from power plants with CCS*, 2012, Available: http://www.ieaghg.org/docs/General_Docs/Reports/2012-03.pdf (Accessed January 12, 2016).
[10] Darrow, K., et al., *Catalog of CHP Technologies* 2015: Available at http://www.epa.gov/sites/production/files/2015-07/documents/catalog_of_chp_technologies.pdf (Accessed January 12, 2015).

capacity produce vastly more renewable energy than wind or solar power systems per unit of capacity installed. In addition, unlike investments in solar and wind power systems, installations of fuel cell capacity can be used by the utility grid as a DER to support capacity and reserve requirements that are used for grid reliability, and as an alternative to increasing utility system transmission and distribution upgrades.

F. Make California More Resilient. Fuel cells uniquely create value as a grid resource to provide firm capacity, the most valuable type of distributed energy resource, with respect to deferring future grid investments and benefiting both the regional transmission system and the local distribution system. Firm capacity (i.e., 100% or near 100% availability) is available day and night, rain or shine, and wind or calm without the additional need for forecasting, planning, or storage. This adds resiliency, reliability, stability, and value to both the transmission and distribution systems, and these benefits translate directly into a more rapid transition to a 100% renewable grid.

Fuel cells can help mitigate an over-reliance on the long distance transmission of electricity from intermittent large scale resources that are located far from load centers. In the event of a grid outage, fuel cell systems can seamlessly island, separate from the utility grid network and support key loads for customers who increasingly require an un-interrupted supply of electricity. Fuel cells have maintained heat and power for critical communication hubs and cell towers, data centers, emergency shelters and other essential services across the Northeast during and after Hurricane Sandy and other severe weather events.

III. Conclusion

The NFCRC appreciates the opportunity to give input on the AB32 Scoping Plan update, based on the August 23 workshop. The forthcoming update to the AB32 Scoping Plan should include GHG reducing fuel cells as a unique technology that can assist California in achieving its 40% GHG emissions reduction goal. The NFCRC will further provide specific recommendations for the expanded role of fuel cell systems in the 2016 update to the AB32 Scoping Plan when the draft document is released in the near future.

Sincerely,

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