MEMORANDUM

To: Marc Campopiano, Esq.
Latham & Watkins, LLP

From: Eric Lu and Emily Weissinger (Bios provided in Attachment 1)
Ramboll

Subject: **ANALYSIS ON THE POTENTIAL ENVIRONMENTAL IMPACTS RELATED TO THE CITY OF SANTA CLARA'S PROPOSED RESOLUTION TO REQUIRE NEW OR MODIFIED SELF-GENERATION FACILITIES TO UTILIZE RENEWABLE GENERATION AND FUEL SOURCES**

Date May 6, 2019

Ramboll
5 Park Plaza
Suite 500
Irvine, CA 92614
USA

T +1 949 261 5151
F +1 949 261 6202
www.ramboll.com

INTRODUCTION

The analysis summarized in this memorandum evaluates the potential environmental impacts associated with a resolution proposed by the City of Santa Clara ("City") City Council that would amend Silicon Valley Power's rules and regulations to require new or modified self-generation facilities to utilize renewable generation and fuel sources. This resolution introduces various potentially significant environmental impacts. Based on our review of the limited technical information in the City's record for this resolution, the technical evidence indicates that the selective requirement imposed in the resolution has the potential to cause significant environmental impacts from the increase in air quality pollutants, greenhouse gas emissions, and other environmental variables. The resolution introduces the likelihood that power demand is addressed by different power generation sources that are not powered by renewable fuel sources. Those power generation sources may have potentially significant environmental impacts that were not analysed by the City in accordance with the California Environmental Quality Act (CEQA).

Although the City indicates the resolution does not need to be evaluated under the state standards for environmental review embodied in CEQA, based on the analysis as presented in this memorandum, there is sufficient scientific data regarding potentially significant impacts resulting from the proposed resolution.

Fuel cell technology is an efficient way to generate electricity and does so without combustion and with little-to-no water use.[1] As a result, fuel cells generate relatively low amounts of criteria pollutant emissions, and have no meaningful effect on an area's water supply.[2] When distributed energy sources like fuel cells are brought online, they reduce the amount of power required from energy sources operating on the margin (i.e., those supplying the last unit of energy demand). Sources operating on the margin are generally those that are the easiest to start up and shut down, but also are the least energy efficient generation sources.[3] When compared to other forms of power production such as power plants that use natural gas, fuel cells

---

[1] See: https://www.energy.gov/sites/prod/files/2015/11/f27/fcto_fuel_cells_fact_sheet.pdf. Accessed: May 2019. Also provided as Attachment 2.
[2] See: https://bloomenergy.com/datasheets/energy-server-es5-300kw. Accessed: May 2019.
[3] See: https://www.bloomenergy.com/whitepapers/fuel-cell-emissions. Accessed: May 2019.

demonstrate clear environmental benefits. This issue should be evaluated as part of the CEQA process to assess if the selective requirement for renewable fuels for self-generation facilities may lead to greater power generation from traditional combustion based natural gas-powered sources. As the demand for electricity increases, increased natural gas power production could have significant environmental effects within the following CEQA technical areas: air quality, health risks, greenhouse gases, hydrology/water quality, noise, energy, utilities and services, and aesthetics. Each of these areas is further explored in the sections below.

Air Quality

Fuel cell technology is characterized by high efficiency energy conversion. This inherently results in lower criteria pollutant emissions per megawatt-hour (MWh) compared to traditional natural gas power generation. The lower criteria emissions achieved by fuel cells can be partially attributed to their ability to convert fuel into electricity without combustion. The degree to which fuel cells out-perform natural gas power production can be quantified by directly comparing emissions factor data for a Bloom Energy fuel cell with data from the primary natural gas power plant in Santa Clara, the Donald Von Raesfeld Power Plant.

Table 1. Criteria Pollutant Emission Factor Comparison between a Bloom Energy Fuel Cell and the Donald Von Raesfeld Power Plant

	DVR Power Plant Reported Emissions[a]			DVR Power Plant Net Generation[b]	Calculated Emission Factors		
Year	**CO (tons)**	**NOx (tons)**	**SOx (tons)**	**(MWh)**	**CO (lbs/MWh)**	**NOx (lbs/MWh)**	**SOx (lbs/MWh)**
2016	20.92	20.83	2.26	934,537	0.045	0.045	0.005
2017	17.33	17.23	1.87	642,620	0.054	0.054	0.006
Average	19.13	19.03	2.06	788,579	0.049	0.049	0.005
Bloom Energy Emission Factors[c][d]					**0.034**	**0.0017**	**Negligible**
% Difference					**-31%**	**-97%**	**-100%**

Notes:

[a] Emissions data queried from the California Air Resources Board at: https://www.arb.ca.gov/app/emsinv/facinfo/facinfo.php. Accessed: May 2019.

[b] Net generation data queried from the U.S. Energy Information Administration at: https://www.eia.gov/electricity/data/browser/. Accessed: May 2019.

[c] Emission factors for the Bloom Energy 300 kilowatt ES-5 obtained from: https://bloomenergy.com/datasheets/energy-server-es5-300kw. Accessed: May 2019.

[d] California Air Resources Board certification of the Bloom Energy 300 kilowatt ES-5 available at: https://ww2.arb.ca.gov/our-work/programs/distributed-generation/current-distributed-generation-executive-orders. Accessed: May 2019.

Abbreviations:

CO – carbon monoxide
DVR – Donald Von Raesfeld
lbs – pounds
MWh – megawatt-hour
NOx – oxides of nitrogen
SOx – oxides of sulfur

As demonstrated in Table 1 above, on a per MWh basis the Bloom Energy fuel cell has emissions 31 to 100 percent lower than the Donald Von Raesfeld Power Plant. The difference in NOx emissions is particularly noteworthy as Santa Clara County has been designated a nonattainment area for ozone and NOx reductions are critical to an area's ozone attainment strategy. It's also important to note that traditional natural gas power plants can also be a source of particulate matter emissions (due in-part to cooling tower usage). Ultimately, an increase in natural gas combustion which could occur as a result of this proposed resolution would potentially result in a significant increase in criteria pollutant emissions and have implications on the area's air quality and attainment status.

Health Risks

Although Ramboll did not calculate the potential health risks associated with this proposed resolution, there is a well-established connection between an ambient or regional increase in criteria pollutant emissions and health impacts on humans, particularly sensitive receptors.[4,5] Given the potential increase in criteria pollutant emissions discussed in the section above, the resolution has the potential to cause health impacts on members of the public. It is also important to note that two of the three natural gas power plants in Santa Clara are located within Senate Bill (SB) 535 disadvantaged communities (see Attachment 3) and the third power plant is located near a residential area. Therefore, these impacts have the potential to disproportionately impact disadvantaged communities and sensitive receptors.

Greenhouse Gases

The high efficiency energy conversion capabilities of fuel cell technology inherently results in their lower greenhouse gas (GHG) emissions on a per MWh. In addition, their high capacity factors (generally > 90%) maximize potential greenhouse gas emission reductions on a per megawatt basis.[6] These recognized benefits are part of the reason why the State of California has established programs[7,8] and passed legislation[9] in support of distributed generation technologies. The degree to which fuel cells out-perform natural gas power production can be quantified by directly comparing emissions factor data for a Bloom Energy fuel cell with data from the Donald Von Raesfeld Power Plant. As shown in Table 2 below, on a per MWh basis the Bloom Energy fuel cell would on average generate 20 percent lower GHG emissions than the Donald Von Raesfeld Power Plant. Ultimately, an increase in natural gas production as a result of this proposed resolution could result in a significant increase in greenhouse gas emissions.

---

[4] See: https://www.epa.gov/ground-level-ozone-pollution/health-effects-ozone-pollution. Accessed: May 2019.
[5] See: https://www.epa.gov/co-pollution/basic-information-about-carbon-monoxide-co-outdoor-air-pollution#Effects. Accessed: May 2019.
[6] See: https://www.bloomenergy.com/whitepapers/fuel-cell-emissions. Accessed: May 2019.
[7] See: http://www.cpuc.ca.gov/sgip/. Accessed: May 2019.
[8] See: https://www.arb.ca.gov/energy/nem/nem.htm. Accessed: May 2019.
[9] See: http://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180SB1339. Accessed: May 2019.

Table 2. Greenhouse Gas Emission Factor Comparison between a Bloom Energy Fuel Cell and the Donald Von Raesfeld Power Plant			
	DVR Power Plant Reported Emissions[a]	**DVR Power Plant Net Generation[b]**	**Calculated Emission Factors**
Year	**(MT CO_2e)**	**(MWh)**	**(lbs/MWh)**
2016	400,837	934,537	946
2017	278,898	642,620	957
Average	339,867	788,579	950
		Bloom Energy Emission Factor[c]	**756**
		% Difference	**-20%**

Notes:
[a] Emissions data queried from the California Air Resources Board at: https://ww2.arb.ca.gov/mrr-data. Accessed: May 2019. While the reported value is for CO_2e, which can include emissions of methane and other GHGs, those other pollutants account for less than 1 percent of the CO_2e total.

[b] Net generation data queried from the U.S. Energy Information Administration at: https://www.eia.gov/electricity/data/browser/. Accessed: May 2019.

[c] Emission factor for the Bloom Energy 300 kilowatt ES-5 obtained from: https://bloomenergy.com/datasheets/energy-server-es5-300kw. Accessed: May 2019. Showing average of reported range.

Abbreviations:
CO_2e – carbon dioxide equivalents
DVR – Donald Von Raesfeld
lbs - pounds
MWh – megawatt-hour
MT – metric ton

Hydrology/Water Quality

While fuel cell systems need a small amount of water on start-up (e.g., 250 gallons), they require no ongoing water use.[10] Therefore, they have virtually no impact on an area's hydrology or water supply. In contrast, thermoelectric power generation requires significant amounts of water for cooling. In 2015, that sector alone made up 41% of the nation's freshwater withdrawals.[11] While many modern thermoelectric plants are moving towards recirculating cooling systems to reduce water withdrawals, water consumption is still significant (mostly due to evaporation loss). While the annual usage of cooling water for the Santa Clara natural gas power plants could not be located online, the Donald Van Raesfeld Power Plant is permitted with a cooling tower with a rated capacity of 34,980 gallons per minute.[12] Even if this cooling water is reclaimed, there will still be potentially significant losses to

[10] See: https://bloomenergy.com/datasheets/energy-server-es5-300kw. Accessed: May 2019.
[11] See: https://www.usgs.gov/mission-areas/water-resources/science/total-water-use?qt-science_center_objects=0#qt-science_center_objects. Accessed: May 2019.
[12] See: http://www.baaqmd.gov/~/media/files/engineering/title-v-permits/b4991/b4991_2013-04_initial-final-permit_02.pdf?la=en. Accessed: May 2019.

evaporation, as well as GHG emissions associated with the conveyance and treatment of that water. The potential impacts on hydrology and water quality, and utilities and service systems that could occur as a result of the proposed resolution should be evaluated.

Noise

Fuel cells do not use combustion and have no moving components; therefore, they are a relatively quiet form of energy production.[13] This is especially true when compared against emergency generators and industrial power plants, in which the latter typically features air-cooled condensers, cooling towers, and turbines/generators. An increase in natural gas combustion-based energy production as a result of this proposed resolution could result in noise impacts on sensitive receptors. This is especially true were there to be increased production at the Gianera Power Plant, which is located adjacent to a residential neighborhood.

Energy

The proposed resolution and its selective renewable fuel usage requirement is likely to impact energy resources, including Silicon Valley Power (SVP) customer choice to use and manage onsite generation resources during normal and emergency conditions. As a result, the City should evaluate the proposed resolution's impact on energy resources and the efficient use of energy by SVP customers.

Other CEQA Considerations

The proposed resolution and its selective renewable fuel usage requirement would specifically impact the future development of energy supplies. As a result, the City should evaluate the proposed resolution's impact on utilities and service systems. Similarly, in the event other power generation such as traditional power plants or solar is required, the proposed resolution's resulting impact on aesthetics and biological and cultural resources should be evaluated. The streamlined features of fuel cells have an environmentally better aesthetic impact than solar fields or traditional natural gas power plants. Likewise, the land footprint for fuel cells can be much smaller than solar fields or traditional natural gas power plants and thus result in a comparably lower impact on biological and cultural resources.

[13] The Bloom Energy 300 kilowatt ES-5 has a noise rating of less than 70 decibels at 6 feet and requires no muffling. See: https://bloomenergy.com/datasheets/energy-server-es5-300kw. Accessed: May 2019.

RAMBOLL

ATTACHMENT 1

Ramboll Bios

ERIC CHEN LU

Principal

Eric Lu has more than 19 years of experience in air quality management and climate change issues. He has expertise with air quality and GHG emissions inventory and reporting, risk assessment, climate action plan development, CEQA, and agency/public stakeholder outreach and communication. He has assisted a variety of clients and entities on complex air quality, GHG, and energy issues including, municipal entities, utilities, and regulatory agencies (e.g., SCAQMD, CARB). He has worked with many private sector clients including oil and gas, manufacturing, landfills, commercial and residential land use development, and renewable energy facilities and often assisted in public outreach and agency communications.
Mr. Lu's experience highlights include leading the effort to develop and prepare a GHG emissions inventory analysis for Newhall Ranch, which achieved the most aggressive GHG mitigation plan to date in California for land use development. He has also managed the development of technical reports to support EIRs, overseeing multi-disciplinary teams. Mr. Lu is a Registered Professional Engineer (PE), a Certified Permitting Professional (CPP), and an Accredited Greenhouse Gas Lead Verifier in California and a Verifier under the Airport Carbon Accreditation (ACA) Program. He has a Bachelor's degree in Chemical Engineering from Brown University and a Master's degree in Chemical Engineering from the University of California, Berkeley.

COURSES/CERTIFICATIONS

Professional Engineer (Chemical) - California (CH6248), 2015
Certified Permitting Professional - South Coast Air Quality Management District (M6053), 2015
Accredited Greenhouse Gas Lead Verifier with sector specialty in Refineries and Cement (ARB Executive Order H-09-037), 2015

MEMBERSHIPS

Air and Waste Management Association (AWMA)

PROJECTS

- Evaluated air quality and climate change impacts including the preparation of complex air emissions inventories (criteria pollutant, toxics, GHGs), air dispersion models and health risk assessments in support of California Environmental Quality Act (CEQA) requirements. Projects have included mixed-use developments, landfills, oil and gas production facilities, commercial developments, and airports. This has included evaluation of construction and operational conditions.

CONTACT INFORMATION

Eric Chen Lu

elu@ramboll.com
+1 (949) 7983650

Ramboll
5 Park Plaza
Suite 500
Irvine, 92614
United States of America

EDUCATION

1996-1999
MS, Chemical Engineering
University of California
Berkeley, Berkeley

1992-1996
BS, Chemical Engineering (Honors)
Brown University, Providence

- Directed the efforts to prepare technical reports as required by CEQA for an oil and gas production facility and a renewable energy facility. This included the preparation of geology/soils, biological resources, cultural resources, air quality, greenhouse gas, noise, hazards, hydrology and water quality, and traffic analyses. Provided strategic assistance and coordinated with lead agency and lead agency consultants in the preparation of the EIRs based on our technical reports.
- Evaluated the air quality and GHG emissions from a landfill in support of technical studies for CEQA. This included the development of emissions inventories for all sources at the landfill and related operations, air dispersion modelling to evaluate near site impacts, and health risk assessment from facility operations. Supported the project in the development of the EIR from the technical reports, assisted with responses to public comments on the EIR.
- Directed the ongoing compliance work at Clean Harbors Westmorland. This includes the maintain of an ambient air monitoring program, health risk assessment preparation, and other compliance evaluations. Assisting with Clean Harbors Buttonwillow to response to DTSC comments regarding an ambient air monitoring plan and human health risk assessment workplan.
- Prepared air quality and greenhouse gas CEQA evaluations as required by the San Joaquin Valley Air Pollution Control District (SJVACPD) for a mixed used development.
- Studied California's Scoping Plan and research evaluating how California can achieve the GHG reduction goals to evaluate and develop significance thresholds for GHG evaluations as required for CEQA. Incorporated evaluation of the Newhall Ranch Supreme Court Decision to inform the pros and cons of potential significance thresholds.
- Studied the potential GHG emission reduction benefits of various GHG related mitigation measures. Developed potential emission estimation methodology to calculate the potential achievable reductions.
- Prepared an analysis of life cycle GHG emission from alternative energy types in support of a solar energy project. Reviewed studies from the literature and placed the studies into context considering the different methods used and boundaries drawn.
- Prepared health risk assessments to evaluate the cancer and noncancer impacts from construction, operational, and freeway emission sources in support of CEQA requirements.
- Assisted various manufacturing and industrial facilities to assess potential air quality emissions including criteria pollutants and toxic air emissions. Assisted various facilities in maintaining compliance with South Coast Air Quality Management District (SCAQMD) and San Diego Air Pollution Control District (SDAPCD) Rule and Regulations. These facilities have included pet food manufacturers, airport/airline facilities, gas production facilities, universities, coatings manufacturers, compost and waste transfer facilities, and pharmaceutical companies. These facilities have encountered issues related to the Regional Clean Air Incentives Market rules (RECLAIM) and Title V. Assisted with annual emissions reporting and permitting.
- Managed and participated in large litigation support teams to complete complex technical analysis including source testing, emissions estimation, health risk assessment, meteorological data evaluation and air dispersion modeling. Provided litigation support in regards to toxic court cases involving oil and gas production facilities, hydrogen sulfide emissions in a city-wide area, mining facilities, paint burn-off ovens, RECLAIM requirements, indoor air quality and cooling tower emissions.
- Designed and implemented ambient air monitors for inorganics and organic compounds. The monitoring was in support of various applications including perimeter monitoring during remediation, operational impact evaluation, air permit compliance requirements, as well as for litigation support.

ENVIRONMENT
& HEALTH

EMILY A WEISSINGER

Senior Managing Consultant

Emily Weissinger's work focuses on air quality engineering, regulatory compliance, and sustainable design. She has expertise in permitting and compliance, emissions estimation, regulatory interpretation, State Implementation Plan development, indoor and ambient air quality sampling, air modeling, health risk assessments, and greenhouse gas reporting and compliance. In addition, she has experience with Leadership in Energy and Environmental Design (LEED) certification, California Environmental Quality Act/National Environmental Policy Act compliance and documentation, and technical support in matters involving litigation.

EDUCATION

MSE, Civil, Environmental, & Sustainable Engineering
Arizona State University, Tempe, AZ

BSE, Civil and Environmental Engineering
Princeton University, Princeton, NJ

COURSES/CERTIFICATIONS

Professional Engineer, Arizona
LEED Accredited Professional
40-hour OSHA HAZWOPER

EXPERIENCE HIGHLIGHTS

Sustainable Design and Operation
Has provided technical support to multiple industries seeking greater sustainability in their operations. This has included developing the documentation and calculations necessary for the successful LEED certification of new construction, as well as auditing energy, water, and waste profiles of existing operations and providing recommendations for improvement.

Greenhouse Gas Reporting and Compliance
Has provided technical support related to greenhouse gas emissions estimation, compliance, and reporting, including the development of greenhouse gas monitoring plans and the annual reporting of emissions through the United States Environmental Protection Agency's Electronic Greenhouse Gas Reporting Tool. Has also contributed to the development of climate action plans for industry and local government.

CONTACT INFORMATION

Emily A Weissinger

eweissinger@ramboll.com
+1 (602) 7347739

Ramboll
2111 East Highland Avenue
Suite 402
Phoenix, AZ 85016
United States of America

Carbon Market Assistance
Has provided strategic greenhouse gas cap and trade compliance assistance to multiple industries seeking to understand and comply with the existing California cap and trade regulation, as well as plan for potential future regulations. This has included reviewing current and proposed regulations and distilling key information for company executives, providing bid advisory services for clients participating in cap and trade auctions, and overseeing calculations related to third-party verification of greenhouse gas offsets for use in California's cap and trade program.

Corporate Air Quality Permitting and Compliance Assistance
Has provided corporate air quality compliance assistance to clients across a multitude of industrial sectors including mining, oil and gas, and manufacturing. Services provided have included permitting, compliance reviews, emissions estimation, indoor and ambient air quality sampling, and annual emission inventory and toxic release inventory reporting.

State Implementation Plan and Emission Inventory Development
Has assisted multiple air agencies in the development of State Implementation Plans (SIPs) for National Ambient Air Quality Standards (NAAQS), a requirement under the Clean Air Act. Individual responsibilities have included inventory development, data processing, regulatory analyses, control measure analysis, inter-agency consultation, public workshops, and comprehensive report writing.

Fugitive Dust Control
Has provided strategic assistance to numerous industries for the control of fugitive dust sources. This work has included authoring fugitive dust control plans, developing and testing innovative dust control measures, and performing comprehensive reviews of international dust-related air quality regulations to facilitate strategic planning.

Air Quality and Health Risk Assessments
Has assisted in the development of multiple air quality and health risk assessments for large-scale infrastructure projects. Individual responsibilities have included quantifying emissions, human exposure, and health risks through the use of various emission factor models as well as Microsoft Access, ArcGIS, HARP2, and AERMOD.

RECENT PUBLICATIONS AND PRESENTATIONS

2016
Washington State's New GHG Regulations: A Case Study for the Future of GHG Regulations for the High-Tech Industry
SESHA 2016 Symposium, May 4, 2016, Scottsdale, Arizona
Presenters: E. Weissinger, M. De Blasi (Fennemore Craig)

2016
The Future of GHG Regulations in Arizona: Clues from CA and WA State
2016 EPAZ Gatekeeper Regulatory Roundup, March 29, 2016, Scottsdale, Arizona
Presenter: E. Weissinger

2015
Comparison of Land, Water, and Energy Requirements of Lettuce Grown Using Hydroponic vs. Conventional Agricultural Methods
Int. J. Environ. Res. Public Health 2015, 12(6), 6879-6891
Authors: G.L. Barbosa, F.D.A. Gadelha, N. Kublik, A. Proctor, L. Reichelm, E. Weissinger, G.M. Wohlleb and R.U. Halden

ATTACHMENT 2

United States Department of Energy
Fuel Cell Technologies Office
Fuel Cell Fact Sheet

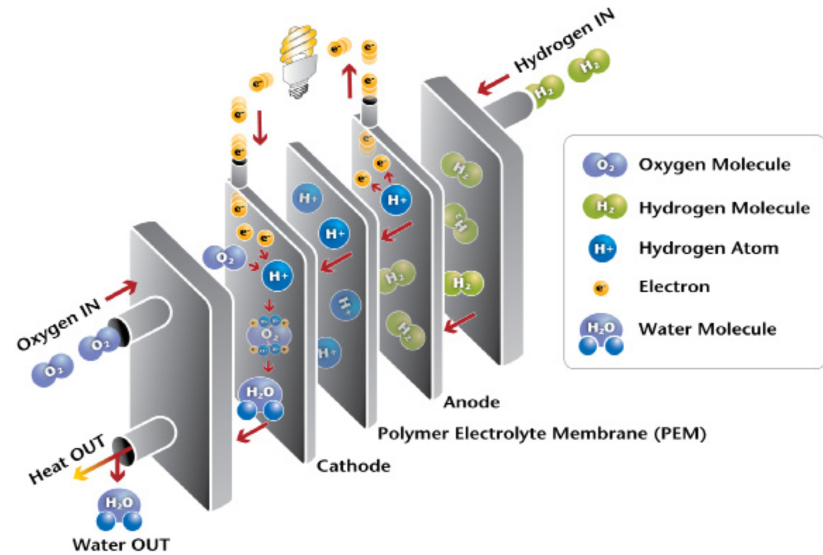
Fuel Cells

Fuel cells are the most energy efficient devices for extracting power from fuels. Capable of running on a variety of fuels, including hydrogen, natural gas, and biogas, fuel cells can provide clean power for applications ranging from less than a watt to multiple megawatts.

Our transportation—including personal vehicles, trucks, buses, marine vessels, and other specialty vehicles such as lift trucks and ground support equipment, as well as auxiliary power units for traditional transportation technologies—can be powered by fuel cells. They can play a particularly important role in the future by enabling replacement of the petroleum we currently use in our cars and trucks with cleaner, lower-emission fuels like hydrogen or natural gas.

Stationary fuel cells can be used for backup power, power for remote locations, distributed power generation, and cogeneration (in which excess heat released during electricity generation is used for other applications). They can take advantage of inexpensive natural gas and low-carbon fuels like biogas, enabling significant efficiency improvement and greenhouse gas reduction when compared to combustion-based power generators.

Fuel cells can power almost any portable application that typically uses batteries, from hand-held devices to portable generators.



Fuel cells directly convert the chemical energy in hydrogen to electricity, with pure water and potentially useful heat as the only byproducts. Hydrogen-powered fuel cells are not only pollution-free, but also can have more than two times the efficiency of traditional combustion technologies.

Why Fuel Cells?

Fuel cells directly convert the chemical energy in hydrogen to electricity, with pure water and potentially useful heat as the only byproducts. Hydrogen-powered fuel cells are not only pollution-free, but they can also have more than two times the efficiency of traditional combustion technologies.

A conventional combustion-based power plant typically generates electricity at efficiencies of 33 to 35%, while fuel cell systems can generate electricity at efficiencies up to 60% (and even higher with cogeneration).

The gasoline engine in today's typical car is less than 20% efficient in converting the chemical energy in gasoline into power that moves the vehicle, under normal driving conditions. Fuel cell vehicles, which use electric motors, are much more energy efficient. The fuel cell system can use 60% of the fuel's energy—corresponding to more than a 50% reduction in fuel consumption compared to a conventional vehicle with a gasoline internal combustion engine. When using hydrogen produced from natural gas, fuel cell vehicles are expected to have well-to-wheels greenhouse gas emissions less than half that of current gasoline-powered vehicles.

In addition, fuel cells operate quietly, have fewer moving parts, and are well suited to a variety of applications.

Excess power produced by intermittent renewable sources like solar and wind can be stored in the form of hydrogen, and either fed back into the power grid when needed or used to power fuel cell electric vehicles. In this way, fuel cells could play an important role in aiding the widespread deployment of clean renewable power sources.

How Do Fuel Cells Work?

A single fuel cell consists of an electrolyte sandwiched between two electrodes, an anode and a cathode. Bipolar plates on either side of the cell help distribute gases and serve as current collectors. In a Polymer Electrolyte Membrane (PEM) fuel cell, which is widely regarded as the most promising for light-duty transportation, hydrogen gas flows through channels to the anode, where a catalyst causes the hydrogen molecules to separate into protons and electrons. The membrane allows only the protons to pass through it. While the protons are conducted through the membrane to the other side of the cell, the stream of negatively-charged electrons follows an external circuit to the cathode. This flow of electrons is electricity that can be used to do work, such as power an electric motor.

On the other side of the cell, air flows through channels to the cathode. When the electrons return from doing work, they react with oxygen in the air and the protons (which have moved through the membrane) at the cathode to form water. This union is an exothermic reaction, generating heat that can be used outside the fuel cell.

The power produced by a fuel cell depends on several factors, including the fuel cell type, size, temperature at which it operates, and pressure at which gases are supplied. A single fuel cell produces roughly 0.5 to 1.0 volt, barely enough voltage for even the smallest applications. To increase the voltage, individual fuel cells are combined in series to form a stack. (The term "fuel cell" is often used to refer to the entire stack, as well as to the individual cell.) Depending on the application, a fuel cell stack may contain only a few or as many as hundreds of individual cells layered together. This "scalability" makes fuel cells ideal for a wide variety of applications, from vehicles (50-125 kW) to laptop computers (20-50 W), homes (1-5 kW), and central power generation (1-200 MW or more).

Comparison of Fuel Cell Technologies

In general, all fuel cells have the same basic configuration — an electrolyte and two electrodes. But there are different types of fuel cells, classified primarily by the kind of electrolyte used. The electrolyte determines the kind of chemical reactions that take place in the fuel cell, the temperature range of operation, and other factors that determine its most suitable applications.

Challenges and Research Directions

Reducing cost and improving durability are the two most significant challenges to fuel cell commercialization. Fuel cell systems must be cost-competitive with, and perform as well or better than, traditional power technologies over the life of the system. Ongoing research is focused on identifying and developing new materials that will reduce the cost and extend the life of fuel cell stack components including membranes, catalysts, bipolar plates, and membrane-electrode assemblies. Low-cost, high-volume manufacturing processes will also help to make fuel cell systems cost competitive with traditional technologies.

For More Information

More information on the Fuel Cell Technologies Office is available at http://www.hydrogenandfuelcells.energy.gov.

Comparison of Fuel Cell Technologies

Fuel Cell Type	Common Electrolyte	Operating Temperature	Typical Stack Size	Electrical Efficiency (LHV)	Applications	Advantages	Challenges
Polymer Electrolyte Membrane (PEM)	Perfluoro sulfonic acid	<120°C	<1 kW - 100 kW	60% direct H_2;[i] 40% reformed fuel[ii]	• Backup power • Portable power • Distributed generation • Transportation • Specialty vehicles	• Solid electrolyte reduces corrosion & electrolyte management problems • Low temperature • Quick start-up and load following	• Expensive catalysts • Sensitive to fuel impurities
Alkaline (AFC)	Aqueous potassium hydroxide soaked in a porous matrix, or alkaline polymer membrane	<100°C	1 - 100 kW	60%[iii]	• Military • Space • Backup power • Transportation	• Wider range of stable materials allows lower cost components • Low temperature • Quick start-up	• Sensitive to CO_2 in fuel and air • Electrolyte management (aqueous) • Electrolyte conductivity (polymer)
Phosphoric Acid (PAFC)	Phosphoric acid soaked in a porous matrix or imbibed in a polymer membrane	150 - 200°C	5 - 400 kW, 100 kW module (liquid PAFC); <10 kW (polymer membrane)	40%[iv]	• Distributed generation	• Suitable for CHP • Increased tolerance to fuel impurities	• Expensive catalysts • Long start-up time • Sulfur sensitivity
Molten Carbonate (MCFC)	Molten lithium, sodium, and/ or potassium carbonates, soaked in a porous matrix	600 - 700°C	300 kW - 3 MW, 300 kW module	50%[v]	• Electric utility • Distributed generation	• High efficiency • Fuel flexibility • Suitable for CHP • Hybrid/gas turbine cycle	• High temperature corrosion and breakdown of cell components • Long start-up time • Low power density
Solid Oxide (SOFC)	Yttria stabilized zirconia	500 - 1000°C	1 kW - 2 MW	60%[vi]	• Auxiliary power • Electric utility • Distributed generation	• High efficiency • Fuel flexibility • Solid electrolyte • Suitable for CHP • Hybrid/gas turbine cycle	• High temperature corrosion and breakdown of cell components • Long start-up time • Limited number of shutdowns

i NREL Composite Data Product 8, "Fuel Cell System Efficiency," http://www.nrel.gov/hydrogen/docs/cdp/cdp_8.jpg

ii Panasonic Headquarters News Release, "Launch of New 'Ene-Farm' Home Fuel Cell Product More Affordable and Easier to Install," http://panasonic.co.jp/corp/news/official.data/data.dir/2013/01/en130117-5/en130117-5.html

iii G. Mulder et al., "Market-ready stationary 6 kW generator with alkaline fuel cells," ECS Transactions 12 (2008) 743-758

iv Doosan PureCell® Model 400 System Specifications, http://www.doosanfuelcell.com/en/solutions/system.do

v FuelCell Energy DFC300 Product Specifications, http://www.fuelcellenergy.com/assets/DFC300-product-specifications1.pdf

vi Ceramic Fuel Cells Gennex Product Specifications, http://www.cfcl.com.au/Assets/Files/Gennex_Brochure_%28EN%29_Apr-2010.pdf

U.S. DEPARTMENT OF ENERGY

Energy Efficiency & Renewable Energy

For more information, visit:
hydrogenandfuelcells.energy.gov

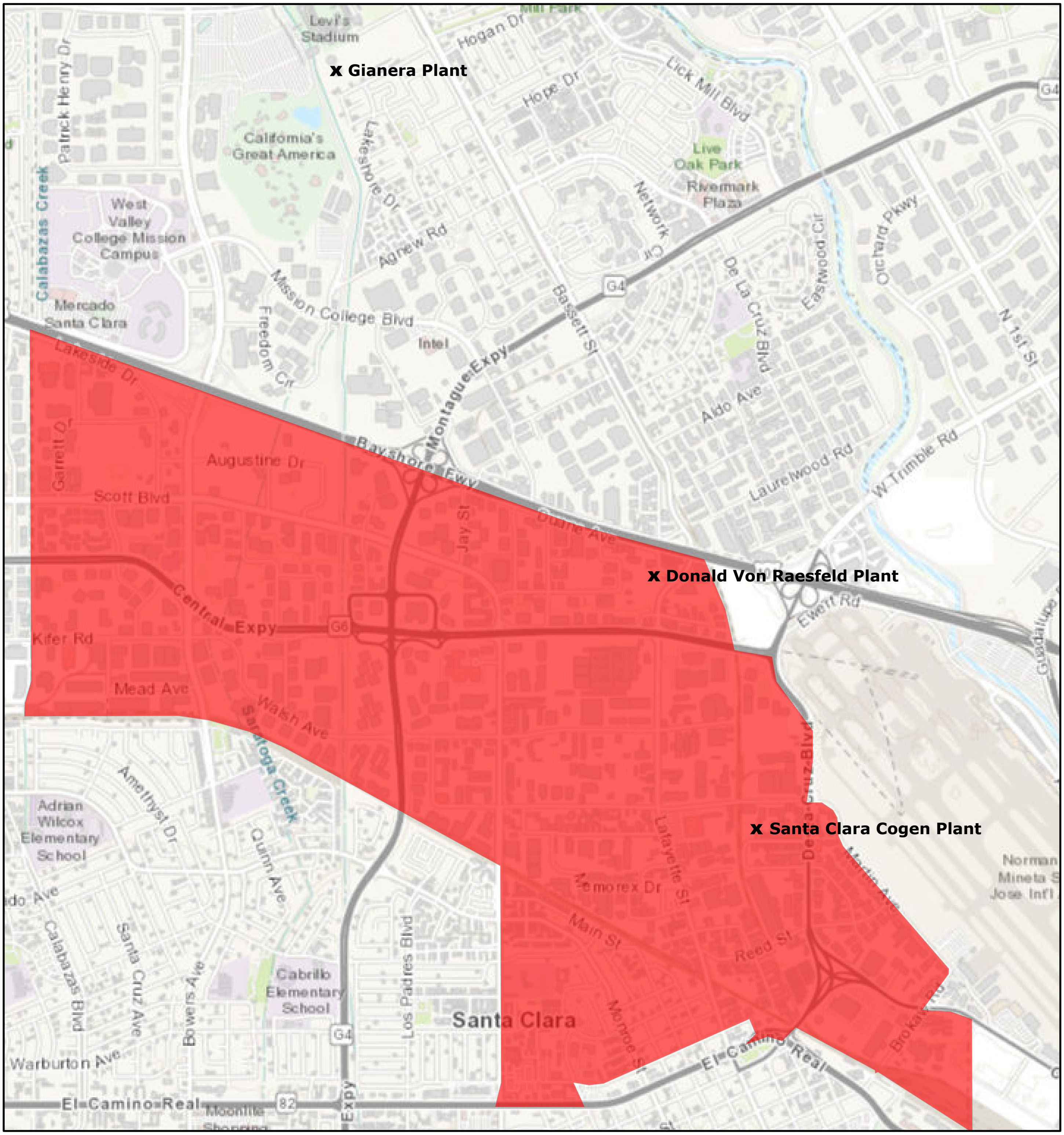
November 2015

Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 10% post consumer waste.

ATTACHMENT 3

Location of Santa Clara Natural Gas Power Plants in Relation to SB 535 Disadvantaged Communities

SB 535 Disadvantaged Communities



May 5, 2019

SB 535 Disadvantaged Communities (June 2018 Update)

1:36,112

0 0.25 0.5 1 mi

0 0.38 0.75 1.5 km

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community