Staff Summary
(Prospective Pathway)
Method 2B LCFS Application for the
Production of Hydrogen from Digester Gas
(ARB Code: HYGN011)

Deemed Complete:	December 21, 2015
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Certified:	TBD

Pathway Summary

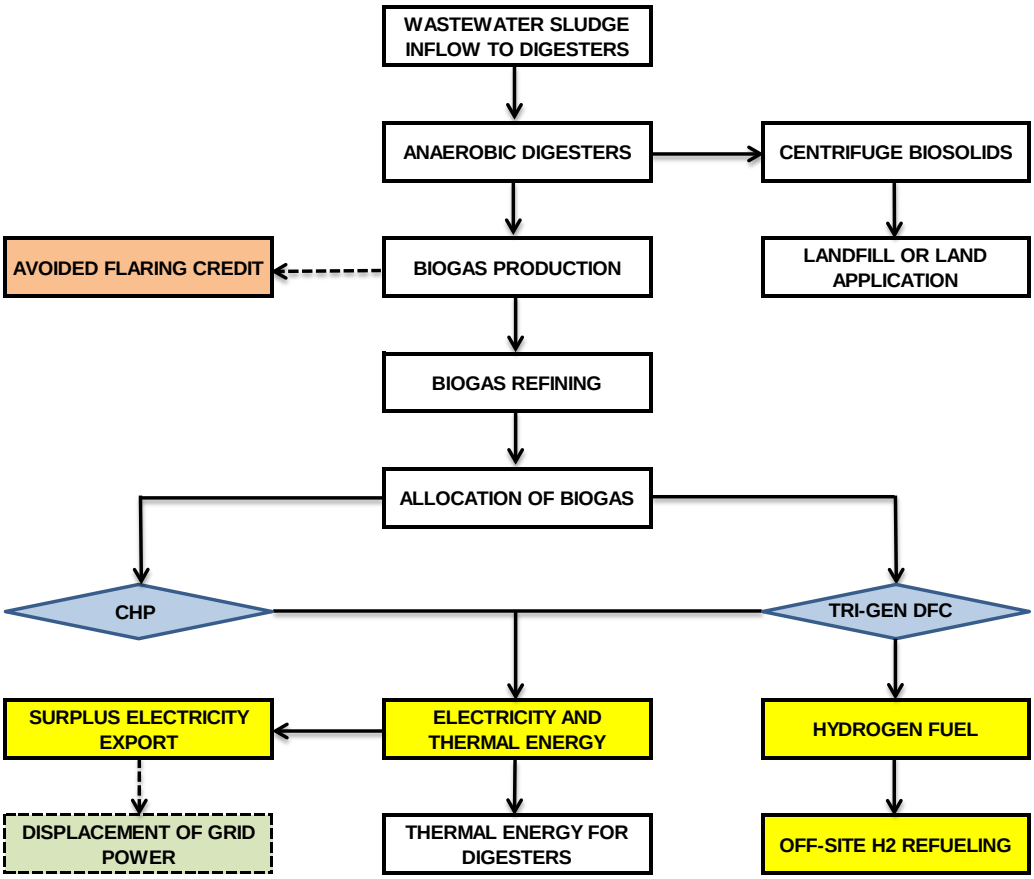
FuelCell Energy (FCE), has applied for a prospective pathway (FCE pathway) for hydrogen fuel produced from biogas derived from the mesophillic anaerobic digestion of wastewater sludge at a publicly owned treatment works (POTW). The biogas produced by the anaerobic digester is cleaned of impurities, and then internally reformed in an integrated hydrogen energy system (Tri-Gen DFC) that produces hydrogen fuel for transportation, electric power for plant operations and export, as well as thermal energy for plant use. The Tri-Gen DFC system was until recently operational at the Orange County Sanitation District Plant #1 (120 mgd) (OCSD), and was producing hydrogen, electric power, as well as thermal energy in a test project to demonstrate the economic and technical viability of high temperature fuel cells employed at CHP units. This pathway being proposed for certification is based upon the three year demonstration project at OCSD.

Along with FuelCell Energy, staff has assessed the feedstock and energy inputs for the Tri-Gen DFC system. Biogas generated in the digesters at OCSD was allocated between the Tri-Gen DFC and the Combined Heat and Power (CHP) plant at OCSD. To determine the carbon intensity (CI) of the hydrogen produced by the FCE pathway, it was necessary to consider the thermal and electrical energy demand within the system boundary established for the FCE pathway that encompasses wastewater sludge digestion, digestate disposal, biogas refining, CHP production, energy production by the Tri-Gen DFC, hydrogen compression, and hydrogen transmission and distribution (T&D). A schematic of the system boundary for the FCE pathway is illustrated in Figure 1 below. Since the FCE pathway is dependent upon the biogas generated by OCSD, it must be designed to work in conjunction with the CHP at OCSD. Hence, the Tri-Gen DFC system is partially responsible, along with the CHP for meeting the electrical energy and thermal energy demands of the process units within the system boundary. Once the internal energy demands of the pathway have been met, any energy not utilized for process is considered to be surplus to the system boundary and is credited to the FCE pathway. The applicant has determined that after the FCE pathway energy demands have been met, surplus electrical energy produced is considered to displace grid-based California average mix electricity.

FIGURE 1

PROPOSED SYSTEM BOUNDARY AND BLOCK FLOW DIAGRAM

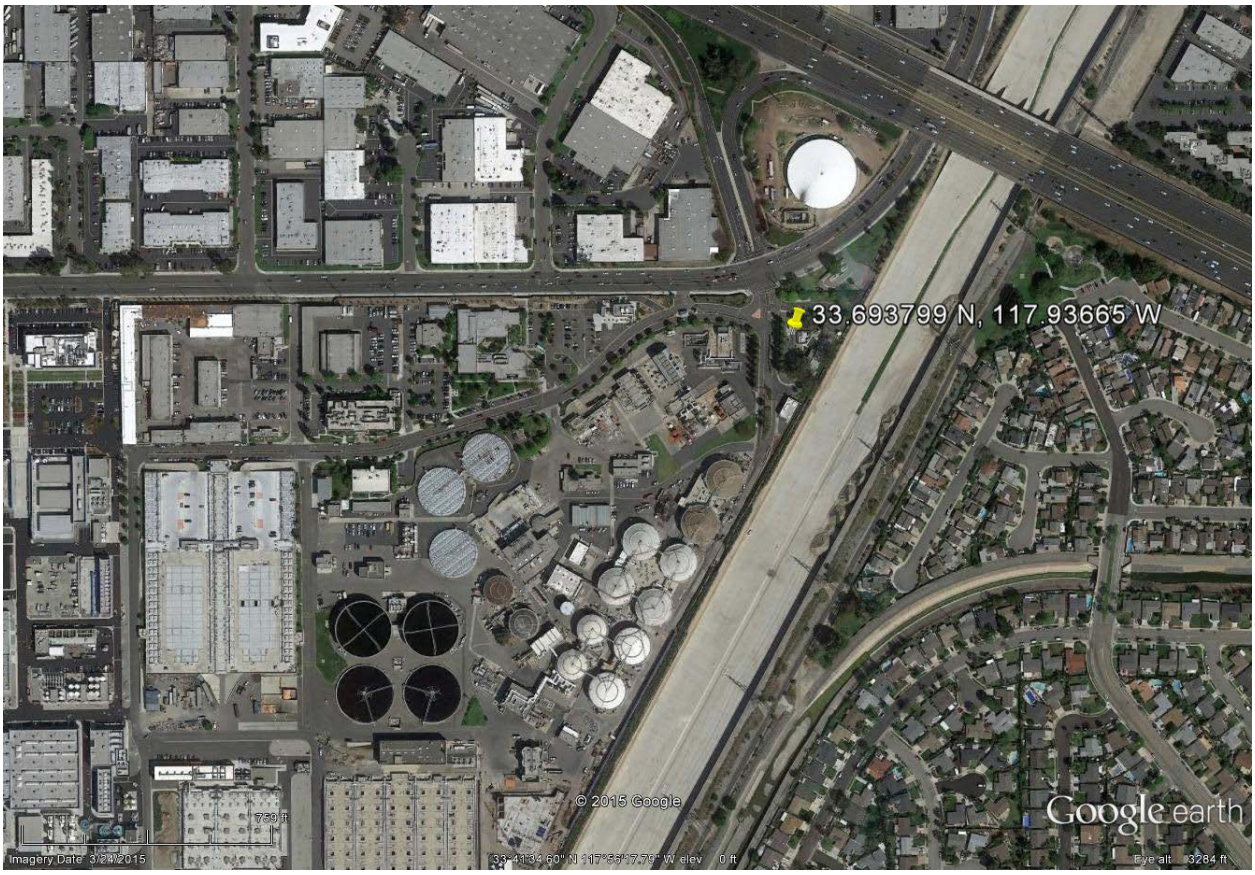
FCE PATHWAY FOR THE PRODUCTION OF HYDROGEN FROM DIGESTER GAS



Facility Location and Coordinates

The FuelCell Energy Tri-Gen DFC system is installed at the Orange County Sanitation District Plant #1 in Fountain Valley, California. The geographic coordinates of OCSD are 33°41'38" N (latitude), and 117°56'12" W (longitude). A satellite view of the OCSD facility can be seen in Figure 2 below:

Figure 2
Satellite View of
Orange County Sanitation District Plant # 1
Fountain Valley, California



Carbon Intensity (CI) of the FuelCell Energy Pathway

The inputs FuelCell Energy used to calculate the Well-to-Wheels (WTW) CI of the FCE pathway are described below.

Electrical and Thermal Energy Demand of the FCE Pathway

The energy balance for the FCE balance is based upon an estimated total electrical energy demand of 495,520 MJ of thermal energy per day, and 149,870 MJ of electrical energy per day. This energy demand is stipulated in the 'RNG' worksheet of a modified version of the CA-GREET v1.8b model. The FCE pathway will be dependent upon an allocation of 44 percent of the biogas yield from Plant #1 at OCSD; the rest of the biogas being sent to the CHP system (business as usual).

Energy Output of the Tri-Gen DFC System

The Tri-Gen DFC system is expected to generate 1,270 kilogram per day of hydrogen fuel which would be used as a transportation fuel, 2,250kW of electric power, and 2 million Btus of thermal energy. The electrical energy produced is the net electricity after subtracting the parasitic load of the Tri-Gen DFC system (705 kW). All of the thermal energy, and part of the electrical energy will be used to meet the energy demands of the process units constrained within the system boundary established for the FCE pathway. The hydrogen fuel produced will be distributed to the nearby hydrogen stations following the hub and spoke distribution model.

Energy Output of the OCSD CHP System

FuelCell Energy has estimated the electrical and thermal energy outputs produced by the CHP system at OCSD, and the corresponding GHG emissions impacts that ensue from biogas utilization in the CHP system. An electrical generating and thermal efficiency of 35 percent and 55 percent was assumed, respectively. Together with the Tri-Gen DFC system, both units adequately meet the electrical and thermal energy demand of the FCE pathway.

Surplus Cogenerated Electricity

Electricity produced by the CHP and the Tri-Gen DFC systems not utilized in the FCE pathway is considered surplus to the system boundary established, and assumed to displace California average electricity mix. After accounting for transmission and distribution losses (6.5 percent), the CI for the FCE pathway reflects a credit for export of 288 million Btus of electrical energy per day.

Avoided Flaring Emissions

The FCE pathway is credited with the GHG emissions avoided as a result of the avoiding flaring of the biogas generated in the anaerobic digesters. The credit is consistent for all pathways in which biogas is derived from the decomposition of organic wastes.

Hydrogen Fuel T&D

Hydrogen fuel produced by the Tri-Gen DFC system exits the pressure swing adsorption (PSA) column at a pressure of 2,600 psi. The fuel pressure is stepped up to 7,000 psi for transport to refueling stations in tube-based tractor trailers. The refueling stations are assumed to be located at a distance of 30 miles from the hydrogen production system. The final discharge pressure for the hydrogen fuel is estimated to be 12,000 psi.

Fugitive Methane Emissions

Fugitive methane emissions were estimated for the FCE pathway, consistent with the assumptions in the ARB internal pathway for biomethane derived from the mesophillic anaerobic digestion of wastewater sludge at a POTW.[1]

Hydrogen Yield

The total hydrogen yield for the FCE pathway is based upon the internal reformation reaction[2] for the methane in biogas conversion according to the stoichiometric equation as follows:

$$CH_4 + 2H_2O \rightarrow 4H_2 + CO_2\ (CO_2 + CO) \qquad (1)$$

A hydrogen-rich gas stream is produced at the anode of the Tri-Gen DFC unit. The off-gas from the anode contains H_2, CO, CO_2, and H_2O; a combination called syngas. The syngas is fed to the water-gas shift (WGS) catalytic reactor where most of the CO is oxidized to CO_2, and some additional hydrogen from the reducing action of the CO is produced.

$$CO + H_2O \rightarrow H2 + CO_2 \qquad (2)$$

The additional yield of hydrogen from the WGS reactor was not factored in calculating the total hydrogen yield. A theoretical yield based on the reformation of methane in biogas was used instead (equation (1) above).

[1] http://www.arb.ca.gov/fuels/lcfs/121514wastewater.pdf

[2] Air Products and Chemicals, 2012. "Validation of an Integrated Hydrogen Energy Station," FOE Cooperative Agreement (DE-FC36-01GO11087), Final Report, October 2012.

The disaggregated inputs discussed above, along with the pathway CI are summarized in Table 1 below:

Table 1
Summary of Disaggregated WTW GHG Emissions for the FCE Pathway

Pathway Disaggregated Item		FCE Pathway GHG Emissions ($g\ CO_2e/day$)
Well-to-Tank (WTT) GHG Emissions		
FCE Process Emissions		34,297,982.25
CHP Combustion Emissions (ICE)		51,902,119.97
Process Fugitive Emissions		26,655,076.21
Digestate Transport		117,777.66
Hydrogen Compression and T&D Emissions		34,297,982.25
Total WTT Emissions		112,972,956.09
Avoided Flaring Credit		(82,413,132.72)
Electricity Displacement Credit		(32,041,889.09)
Net WTT GHG Emissions		(615,232.11)
Tank-to-Wheels GHG Emissions		0.00
Well-to-Wheels (WTW) GHG Emissions	**(A)**	**(615,232.11)**
Fuel Energy Produced (MJ/day)	**(B)**	**748,239.89**
Hydrogen Fuel CI (gCO2e/MJ)	**(A / B)**	**(0.82)**

The proposed Lookup Table entry for the FCE pathway is presented in Table 2 below:

Table 2
Proposed Lookup Table Entries for Fuel/Feedstocks

Fuel	Pathway Identifier	Pathway Description	Carbon Intensity Values (gCO_2e/MJ)		
			Direct Emissions	Land Use or Other Indirect Effects	Total
Hydrogen	HYGN011	2B Application*: Hydrogen produced in a fuel cell using biogas derived from the mesophilic anaerobic digestion of wastewater sludge, with electricity co-product credit.	(0.82)	0.00	(0.82)

* Specific Conditions Apply.

Applicable Operating Conditions

The FCE pathway described in this Staff Summary is a "prospective pathway" based upon design considerations, as well as limited operational data from a three-year demonstration project that has since concluded at the OCSD. The following constraints are imposed on the use of this prospective pathway and the CI:

1. The applicant shall not use the CI of the prospective FCE pathway for purposes of claiming LCFS credits, or engage in the trading of such credits until the CI of the fuel has been finalized by the Executive Officer of the Air Resources Board.

2. The CI being proposed for the FCE pathway is based upon information submitted to the ARB in support of a prospective pathway. Any changes in feedstock, design, process, assessed parasitic load, energy output, or any other modeled parameter originally proposed in the Method 2B LCFS application will invalidate the CI ascertained for the FCE pathway.

3. The applicant must update the LCFS application and request a provisional CI after one quarter of commercial production has been completed.

Staff Analysis and Recommendations

ARB staff has reviewed the application and has replicated the CI value calculated for the FCE pathway using the modified version of the CA-GREET v1.8b model.
Based upon this preliminary assessment using submitted information, staff has corroborated the estimated CI for the pathway proposed by the applicant. Since the

applicant has only provided limited process modelling and operating data, staff recommends that the Method 2B LCFS application be approved as a prospective pathway.

Fuels with prospective CIs are not eligible to claim credits under the LCFS. To claim credits, the applicant must provide one quarter of operational data once commercial production has commenced. ARB will then complete an updated lifecycle analysis and make necessary adjustments to the originally certified prospective CI if warranted, and approve a provisional CI for the pathway being considered in this application.
To confirm compliance with updated operating conditions, the Executive Officer may reevaluate any aspect of the review at will, and revise the certification to reflect new information. At any time after certification, the Executive Officer may increase the CI values upon determination that the provisional CI underestimates fuel CI, until evidence of hydrogen production is received (Cal. Code Regs. tit. 17, § 95486, subd. (e)(3)(K) (original LCFS); Cal. Code Regs. tit. 17, § 95488, subd. (c)(5)(L) (from January 1, 2016)).