CALIFORNIA ENERGY COMMISSION

California Energy Commission

Clean Transportation Program

**FINAL PROJECT REPORT**

# Emeryville 2 Hydrogen Fueling Station

**Prepared for: California Energy Commission**

**Prepared by: Messer North America, Inc.**

**Gavin Newsom, Governor**

**December 2020 | CEC-600-2020-061**

# California Energy Commission

David Hannay
Jennifer Yan
Mike Ciotti
Alessandra Martin
**Primary Authors**

Messer North America, Inc.
5976 W. Las Positas Blvd.
Pleasanton, CA 94588
Messer North America, Inc. Website (www.MesserAmericas.com)

**Agreement Number: ARV-14-018**

Andrew Hom
**Commission Agreement Manager**

Elizabeth John
**Office Manager**
**ADVANCED FUELS AND VEHICLE TECHNOLOGIES**

Hannon Rasool
**Deputy Director**
**FUELS AND TRANSPORTATION**

Drew Bohan
**Executive Director**

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- City of Emeryville
- Toyota
- Department of Food and Agriculture/Division of Measurement Standards
- Linde ATZ
- California Fuel Cell Partnership
- Broadlux
- California Energy Commission
- Bennett Pump
- Smart Chemistry
- South Coast Air Quality Management District
- Honda

# PREFACE

Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007) created the Clean Transportation Program, formerly known as the Alternative and Renewable Fuel and Vehicle Technology Program. The statute authorizes the California Energy Commission (CEC) to develop and deploy alternative and renewable fuels and advanced transportation technologies to help attain the state's climate change policies. Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013) reauthorizes the Clean Transportation Program through January 1, 2024, and specifies that the CEC allocate up to $20 million per year (or up to 20 percent of each fiscal year's funds) in funding for hydrogen station development until at least 100 stations are operational.

The Clean Transportation Program has an annual budget of about $100 million and provides financial support for projects that:

- Reduce California's use and dependence on petroleum transportation fuels and increase the use of alternative and renewable fuels and advanced vehicle technologies.
- Produce sustainable alternative and renewable low-carbon fuels in California.
- Expand alternative fueling infrastructure and fueling stations.
- Improve the efficiency, performance and market viability of alternative light-, medium-, and heavy-duty vehicle technologies.
- Retrofit medium- and heavy-duty on-road and nonroad vehicle fleets to alternative technologies or fuel use.
- Expand the alternative fueling infrastructure available to existing fleets, public transit, and transportation corridors.
- Establish workforce-training programs and conduct public outreach on the benefits of alternative transportation fuels and vehicle technologies.

To be eligible for funding under the Clean Transportation Program, a project must be consistent with the CEC's annual Clean Transportation Program Investment Plan Update. The CEC issued PON-13-607 to develop infrastructure necessary to dispense hydrogen transportation fuel and to support hydrogen refueling operations prior to large-scale roll-out of Fuel Cell Vehicles (FCVs). In response to PON-13-607, the recipient submitted an application which was proposed for funding in the CEC's notice of proposed awards May 1, 2014 and the agreement was executed as ARV-14-018 on October 16, 2014.

# ABSTRACT

Messer North America, Inc. has successfully designed, constructed, commissioned and opened the Emeryville Hydrogen Refueling Station which is approved to sell hydrogen by the kilogram by the California Department of Food and Agriculture/Division of Measurement Standards. This station is open to the public, accepts most major credit cards, and performs refueling of fuel cell electric vehicles in three minutes at both 350 bar and 700 bar hydrogen tank pressures. This final report describes the performance, economic benefits, and local impact of the project and summarizes the operational data collected under Task 5 Data Collection and Analysis.

**Keywords**: Fuel cell electric vehicles, Emeryville Hydrogen Refueling Station, hydrogen

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# EXECUTIVE SUMMARY

Hydrogen fuel cell electric vehicles and hydrogen refueling stations are expected to play key roles in California as the state transitions to lower-carbon and zero-emission vehicle technologies for light-duty passenger vehicles, transit buses, and truck transport fleets. Numerous government regulations and policy actions identify fuel cell electric vehicles as a vehicle technology that will be available to meet the California Air Resources Board Zero Emission Vehicle Regulation and the governor's Zero Emission Vehicle Mandate. More specific actions to bring fuel cell electric vehicles to California markets are specified in the governor's Zero Emission Vehicle Action Plan.

Hydrogen fuel cell electric drive technology offers tremendous potential for the light-duty passenger vehicle market and medium- and heavy-duty truck and bus markets. Fuel cell electric vehicle passenger vehicles can drive more than 300 miles on a tank of hydrogen and can be refueled in three to four minutes the way gasoline passenger vehicles are fueled. They have zero tailpipe emissions, while the carbon footprint of these vehicles is nearly the same as plug-in electric vehicles. The technology can be readily scaled up for sport utility vehicles, family passenger vans, pick-up trucks, urban package and beverage delivery trucks, and even heavy-duty trucks and buses. Most auto industry analysts and agencies view fuel cell electric drive technology as a complement to battery electric drive technologies, rather than as a competing technology. Both battery and fuel cell electric vehicle technologies will be needed in California to achieve the zero emission vehicle deployment goals.

In contrast to battery electric and plug-in hybrid electric vehicles that can be charged in home settings, fuel cell electric vehicles require a new network of refueling stations that dispense pressurized hydrogen for consumer use. This has meant that the auto industry and station development industry have had to co-develop two new technologies in parallel: hydrogen refueling infrastructure and hydrogen fuel cell electric vehicles. Fuel cell electric vehicles cannot be widely marketed and sold to consumers without a minimum network of refueling stations available.

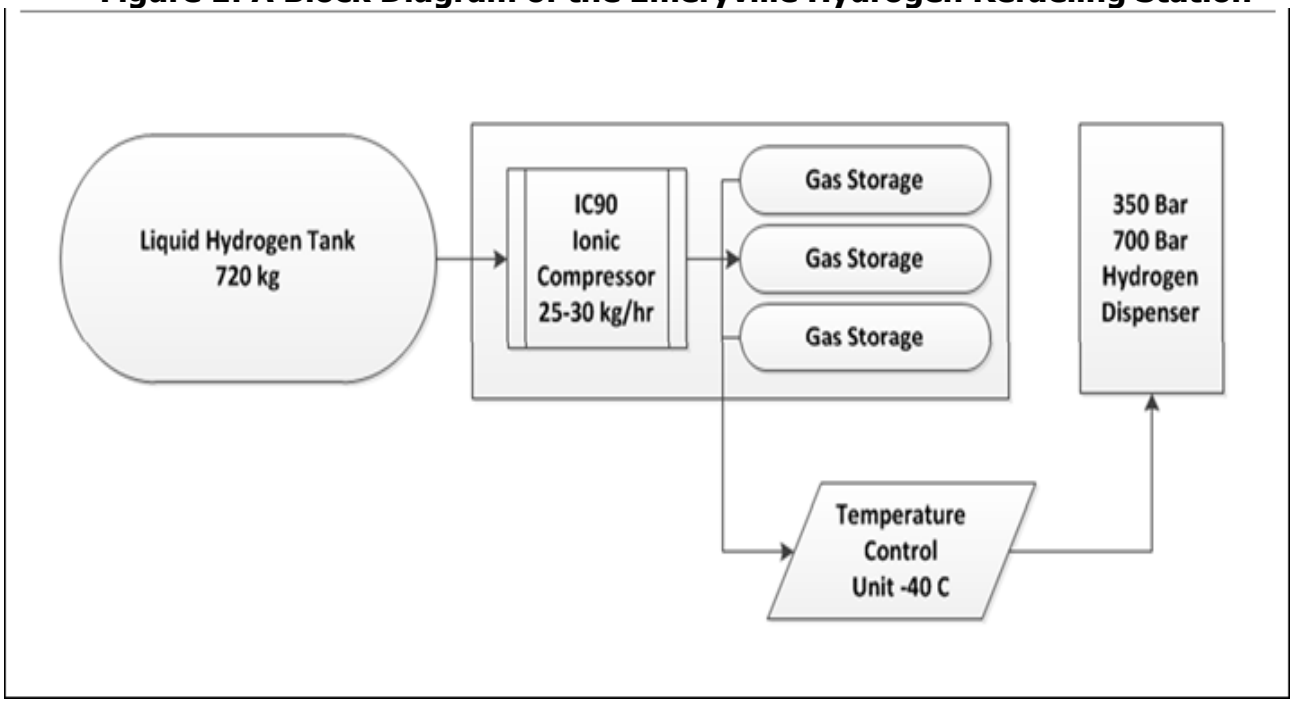
Messer North America, Inc. has proven at the Emeryville Hydrogen Refueling Station that the ATZ IC90 compressor system is capable of performing fast cold fills for both 350 bar and 700 bar light duty hydrogen vehicles with up to 5 kilograms of onboard hydrogen storage. This station stores liquid hydrogen on site and utilizes the ATZ IC90 high throughput hydrogen compressor, which has the capability to scale with the growing light duty fuel cell electric vehicle market. The dual hose dispenser allows for filling of both 350 bar and 700 bar class hydrogen vehicles with tanks less than 10 kilograms.

Messer North America, Inc. has also proven the station's capability of accurately dispensing hydrogen by being approved to sell hydrogen by the kilogram by the California Department of Food and Agriculture/Division of Measurement Standards.

# CHAPTER 1:
# Station Design and Construction

Messer North America, Inc. utilized the ATZ IC90 ionic compressor for hydrogen compression for increased capacity and efficiency. This is the Messer North America, Inc. standard technology for future stations. The Emeryville Hydrogen Refueling Station stores 2400 kilograms (kg) of liquid hydrogen on site and dispenses the hydrogen via high pressure storage tubes which are supplied from the ATZ IC90 compressor as shown in Figure 1.

**Figure 1: A Block Diagram of the Emeryville Hydrogen Refueling Station**




Source: Messer North America, Inc.

The ATZ IC90 station compressor can sustain a flow rate of 25 to 30 kg per hour depending on inlet temperature and pressure which varies due to ambient conditions, utilization, and liquid tank controls. Additionally the station is designed with room for a second ATZ IC90 compressor to be installed in the same compressor container, which could double the station performance.

## 1.1 Timeline

The timetable from the proposal is shown below in Table 1. The planned date for each major milestone is shown with the actual date and justification for changes to the schedule. Overall the technical aspects of the project proceeded on time while the project development, site selection, and local jurisdiction approval took longer than anticipated.

**Table 1: Project Timetable**

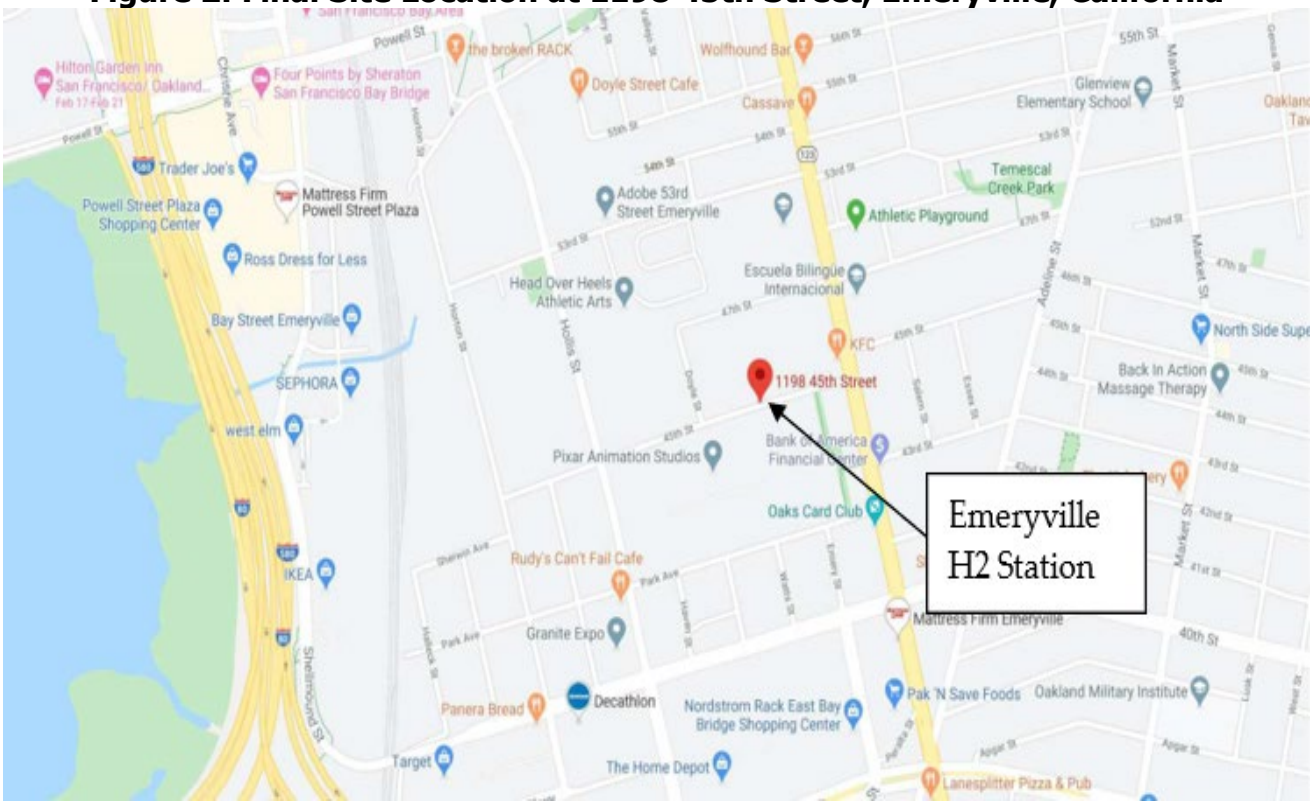
| Event | Target Date | Actual Date |
|---|---|---|
| Anticipated Contract Execution | August-17 | September-17 |
| Project Kick Off (Authority to Proceed) | October-18 | October-18 |
| Secure Planning Approval and Building Permits | May-19 | May-19 |
| Equipment Released for shipment to site | May-15 | Apr-16 |
| Begin Site Work (concrete, trenching, excavation) | May-19 | May-19 |
| Install | June-19 | June-19 |
| Substantial Completion | July-19 | August-19 |
| Commissioning | August-19 | August-19 |
| DMS/Hystep | September-19 | September-19 |
| Open | November-19 | November-19 |

Source: Messer North America, Inc.

## 1.2 Location

The Emeryville Hydrogen Refueling Station is located at 1198 45th Street, Emeryville, CA 94583 shown in Figure 2.

**Figure 2: Final Site Location at 1198 45th Street, Emeryville, California**

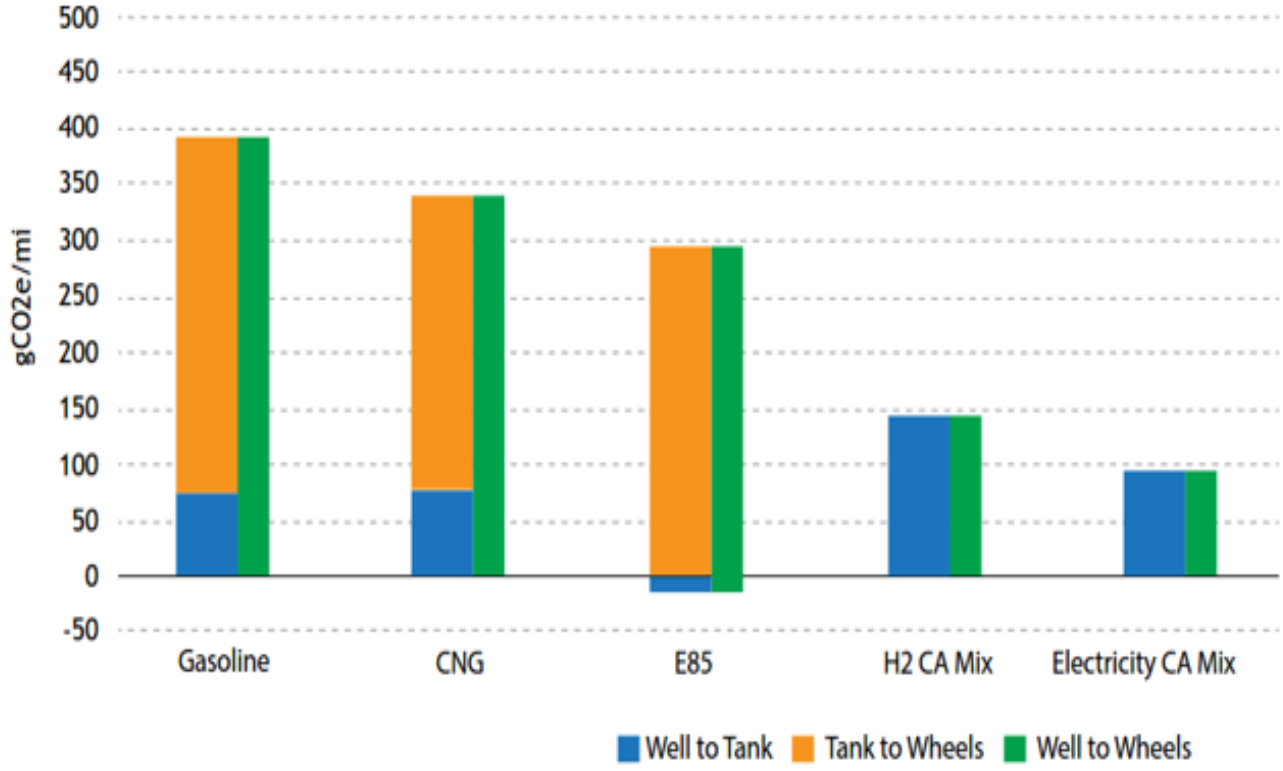



Source: Messer North America, Inc.

## 1.3 Environmental impacts

From station construction through the first four months of operation since the Emeryville station was commissioned, there have been zero incidents that have negatively impacted the environment. From station commissioning to the end of June 2019, 18,900 kg of hydrogen was dispensed. Assuming a fuel cell electric vehicle (FCEV) delivers 60 miles/kg of hydrogen, there was a GHG emission reduction of 272.7 metric tons. This assumes the difference in emission between gasoline and hydrogen is 240 grams of carbon dioxide equivalent per mile, as taken from the CaFCP report based on the Argonne National Lab GREET V1_2013 model shown in Figure 3. These results show a positive impact to the environment.

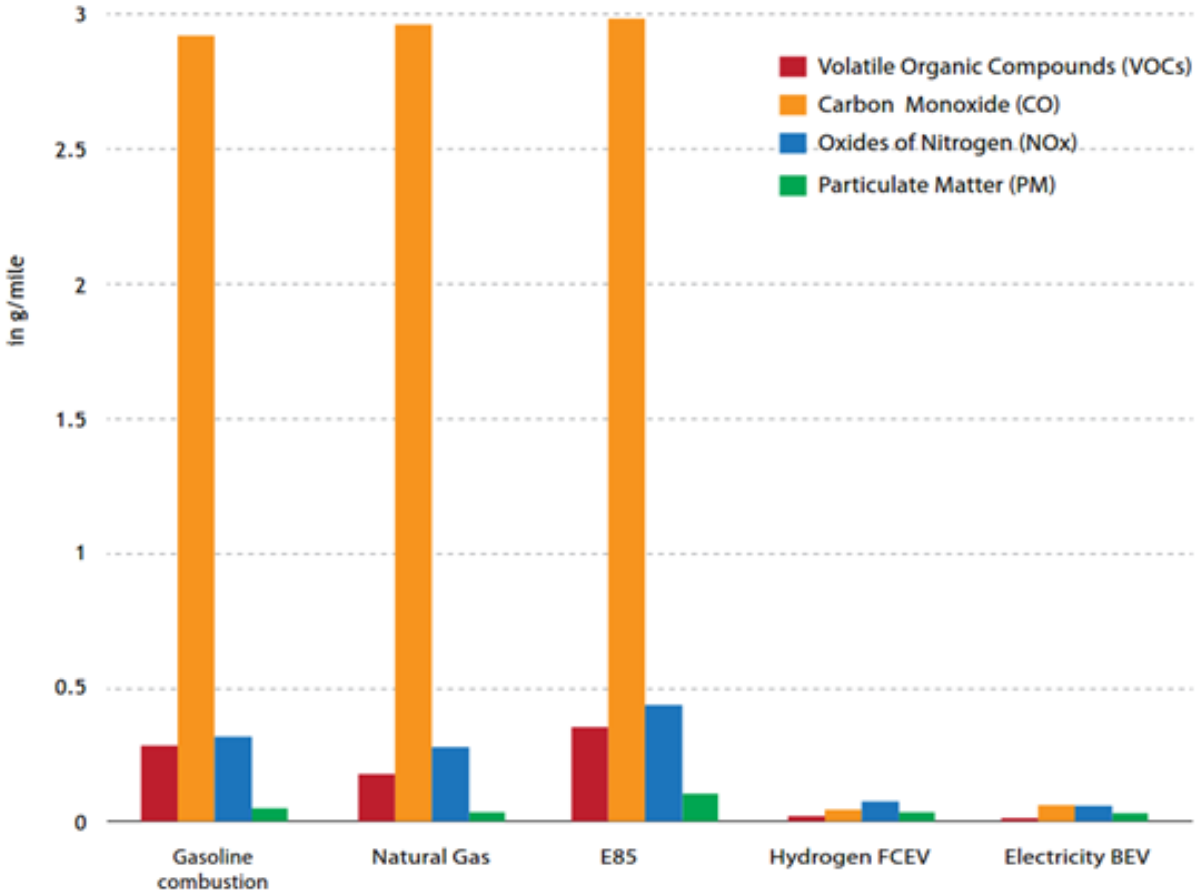
**Figure 3: Greenhouse Gas Emissions based on the Argonne National Lab GREET V1_2013 model**




Source: Messer North America, Inc.

Additionally, there is a reduction in volatile organic compounds, carbon monoxide, oxides of nitrogen, and particulate matter with the displacement of gasoline. Figure 4 shows the reduction.

**Figure 4: GREET Model Results for Criteria Pollution based on the Argonne National Lab, GREET V1_2013 model**

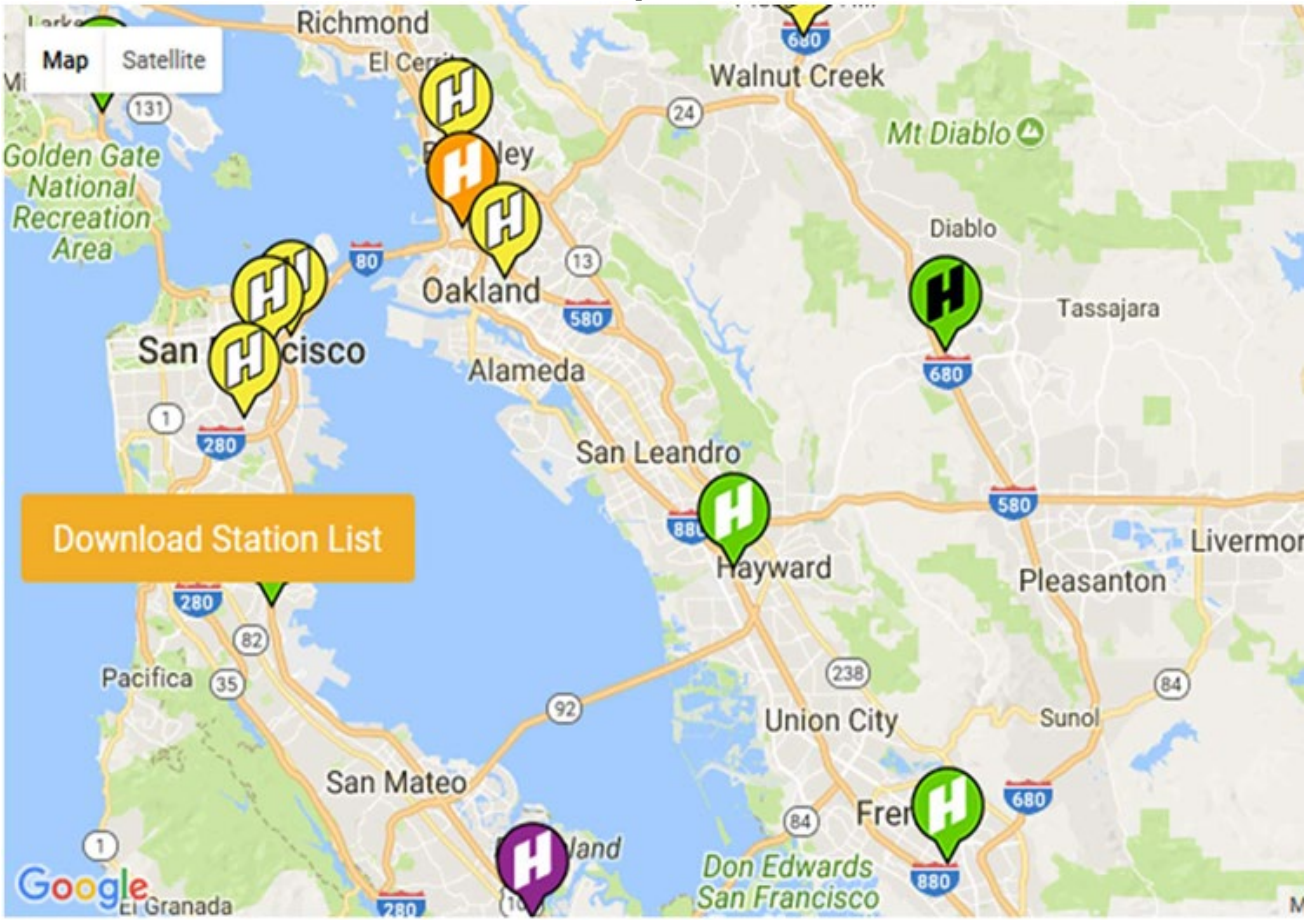



Source: Messer North America, Inc.

## 1.4 Station's place in the fueling network

Emeryville is an emerging hydrogen fuel market. The station is located at the AC Transit Bus maintenance facility and is off Interstate 80 in Alameda County. This location is in the cluster of fuel stations in Alameda and Contra Costa Counties and is used by commuters to the area. The location is shown on the CAFCP website, http://cafcp.org/stationmap, and in Figure 5.

**Figure 5: Emeryville Hydrogen Refueling Station is in the Alameda & Contra Costa County cluster**




Source: Messer North America, Inc.

## 1.5 Photographs of the finished station

The following photos show the completed filling station below in Figures 6 through 10. The station is open to the public, however the liquid hydrogen tank and ATZ IC90 compressor are behind the wall and fence inside the equipment pen. The site is easily viewed from the street.

**Figure 6: Station Photos**


Source: Messer North America, Inc.

**Figure 7: Station Photos**


Source: Messer North America, Inc.

**Figure 8: Station Photos**


Source: Messer North America, Inc.

**Figure 9: Station Photos**

Source: Messer North America, Inc.

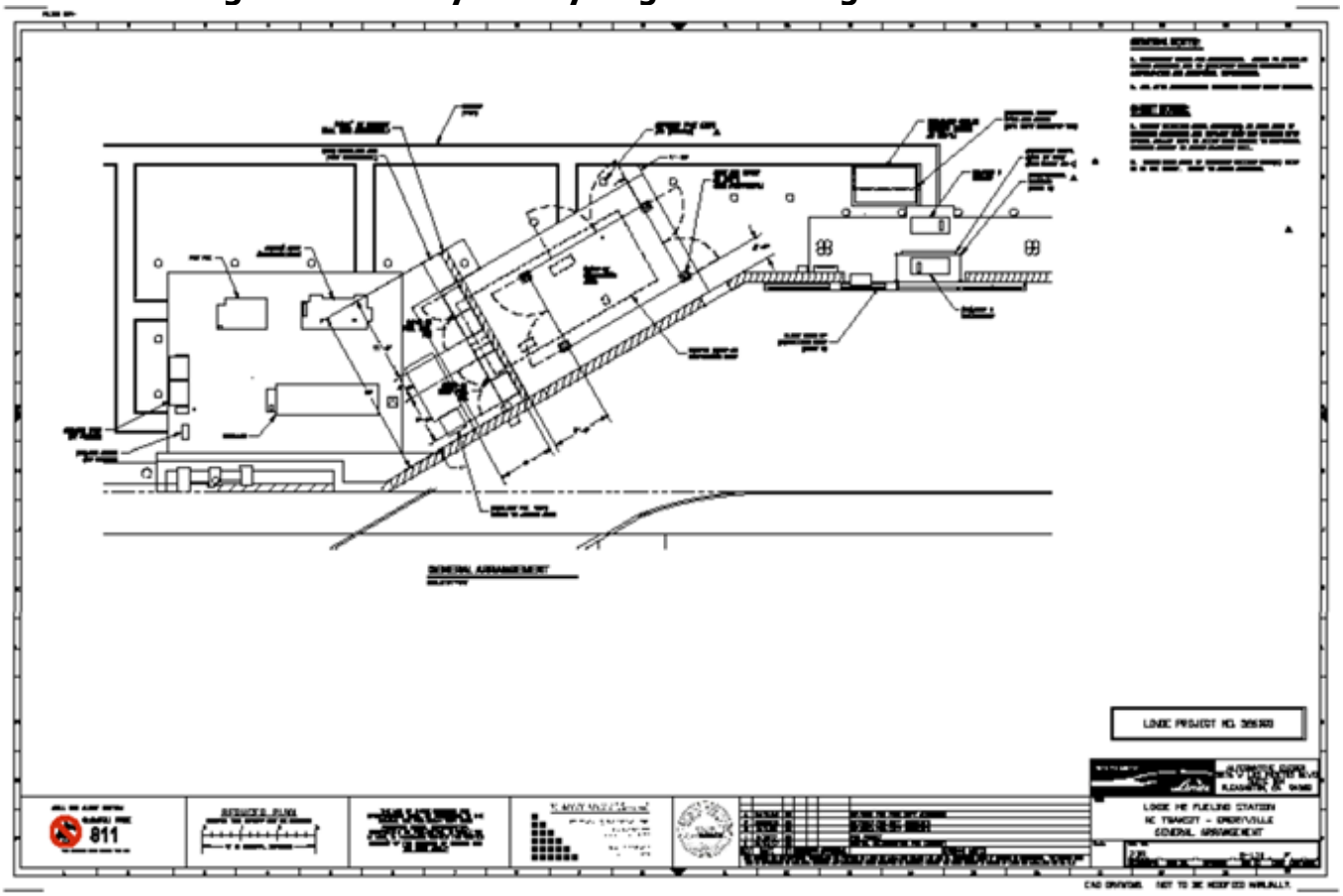
**Figure 10: Station Photos**


Source: Messer North America, Inc.

## 1.6 Site Drawings

The plot plan for the Emeryville Hydrogen Refueling Station is shown below in Figure 11. The proper setbacks for liquid hydrogen and high pressure gas storage fit well on the site. Several improvements to the overall equipment layout have been identified and planned for implementation in future sites. The most significant change is that the high pressure storage shown between the ATZ IC90 and liquid tank are planned to be integrated into the ATZ IC90 container which will reduce the overall footprint. Additionally, the ATZ IC90 controls system will be installed in a remotely located panel to reduce the air purge requirements and power consumption.

**Figure 11: Emeryville Hydrogen Refueling Station Plot Plan**



Source: Messer North America, Inc.

## 1.7 Project costs and funding received from the California Energy Commission (CEC)

The total cost for the new station is $1,728,286 which was considerably lower than the approved budget of $2,133,300.00.

## 1.8 List of Major Subcontractors

Table 2 below shows the subcontractor list for the Emeryville Hydrogen Refueling Station

**Table 2: Emeryville Hydrogen Refueling Station – Subcontractor List**

| Vendor Name | Address | Scope of Services | Value |
|---|---|---|---|
| Apex Refrigeration Services Bennett Pump | 1 Winemaster Way, Lodi, CA 95240 | Refrigeration Services | $11,688 |
| Broadlux CTE | 1218 E.Pontaluna Rd, Spring Lake, MI 49456 PO Box 7303, Laguna Niguel, CA 92607 | Dispenser Certification | $10,100 |
| First Element Fuel E-Tech, Inc. | 730 Peachtree Street, Atlanta, GA 5151 California Ave, Irvine, Ca. 92617 | Point of Sale Equipment | $29,065 |
| Kaiser Compressors Linde | 1910 Mark Ct Ste 130, Concord CA 94520 | Engineering Services | $15,918 |
| Melrose Metal Fabrication T Mitchell Engineers | PO Box 946, Fredericksburg, VA 22404 100 Mountain Ave, Murray Hill, NJ 07974 | Dispenser Certification | $27,525 |
| WEH | 44533 S. Grimmer Blvd, Fremont, CA 94538 14256 Doolittle Dr, San Leandro, CA 94577 24903 Laguna Edge Dr, Katy, TX 77494 3401 La Grande Blvd. Sacramento, CA | General Contractor | $271,543 |
| Smart Chemistry Vector One, LLC | PO Box 852, Summit, NJ 07901 | Air Compressor Services Major Equipment | $9,647 |
| | | Supply Metal Fabrications | $1,005,862 |
| | | Electric Services | $25,433 |
| | | H2 Fueling Equipment Gas Testing Services | $63,890 |
| | | Project Engineering | $19,335 |
| | | | $6,780 |
| | | | $79,603 |

Source: Messer North America, Inc.

# CHAPTER 2:
# Data Collection and Analysis

The goal of this task is to collect at least 12 months of data on the performance, economic benefits and local impact of the project throughout the term of the project and to analyze the sustainability of the Emeryville Hydrogen Refueling Station. The usage of the station during the writing of this report and since initial commissioning is as shown below in Table 3. We will continue to monitor and report on the station performance over the next 12 months.

**Table 3: Usage of the Emeryville Hydrogen Refueling Station**

| Month | Kg |
|---|---|
| Sep-18 | 24.78 |
| Oct-18 | 51.28 |
| Nov-18 | 294.72 |
| Dec-18 | 604.77 |
| Jan-19 | 1082.33 |
| Feb-19 | 1384.96 |
| Mar-19 | 1478.16 |
| Apr-19 | 1600.19 |
| May-19 | 1511.26 |
| Jun-19 | 1831.42 |
| Jul-19 | 739.01 |
| Aug-19 to Nov-19 | Down for Tank Upgrade |
| Dec-19 | 668.18 |
| Jan-20 | 1045.24 |

Source: Messer North America, Inc.

## 2.1 Hydrogen Supply and Performance Statistics

The hydrogen supply for the Emeryville Hydrogen Refueling Station was obtained from a production source located in the Los Angeles area. This same supply was used for the entire funded period of the project and is planned to remain the supply source in the future with potentially additional supply from green sources as discussed in Section 2.5 below. The performance statistics of the Emeryville project from September 2018 to January 2020 are shown below in Table 4.

**Table 4: Emeryville Hydrogen Refueling Station Statistics from 9/2018 to 1/2020**

| Description | Value |
|---|---|
| Total kg of Hydrogen Dispensed, kg | 12,316.27 |
| Average kg/day | 33 |
| Approximate % of H70 | 99 |
| Approximate % of H35 | 1 |
| Number of Days Vehicles Filled | 372 |
| Number of Transactions (~Vehicles Filled) | 3427 |
| Average fill (kg) | 3.59 |
| Average Transactions per day | 9.2 |
| Total Gallons of Gasoline equivalent displaced (1 gallon = 0.997 kg) | 12,279 |

Source: Messer North America, Inc.

## 2.2 Current and Planned use of Renewable Energy

The hydrogen at the Emeryville Hydrogen Refueling Station is planned to be 33 percent renewable, either by purchasing credits to meet 33 percent renewables or delivering renewable hydrogen from a facility from outside the state to meet the 33 percent requirements.

## 2.3 Energy Efficiency

The ATZ IC90 has a 73 percent isentropic efficiency. The entire fuel station electrical consumption can vary due to ambient temperature and station utilization. The station requires a base load for the refrigeration system which cycles on and off automatically to maintain the cold fill heat exchangers at -40 C. On a per kg basis the refrigeration energy is reduced by taking advantage of the cold temperatures in the liquid hydrogen tank. These cold temperatures cool the cold fill heat exchangers and reduce the refrigeration system load. This is more efficient than using only electricity to maintain the cold temperature.

Messer North America, Inc. has also improved site power consumption at the Emeryville Hydrogen Refueling Station by eliminating the need for purged air cabinets by installing the cabinets outside the classified area.

## 2.4 Economic Development

During construction, hours worked by contractors were approximately 1,672 hours/month for five months. This translates to 10 full time jobs during the five months of construction. For operation and maintenance, Messer North America, Inc. anticipates 10-20 percent of a full time equivalent in the early years growing thereafter based on volume and station utilization. During construction, commissioning, Department of Food and Agriculture/Division of Measurement Standards testing, original equipment manufacturer testing, and public events,

significant business has been given to local vendors, labor, hotels and restaurants. Continued economic development would include this station's contribution to a new market supporting local sale of FCEVs.

## 2.5 Life Cycle Greenhouse Gas Emissions

This project reduces greenhouse gas emissions through the supply of a low carbon fuel, hydrogen, for zero emission vehicles. Hydrogen fuel cell vehicles reduce greenhouse gas emissions up to 40 percent compared to conventional gasoline-powered vehicles on a well-to-wheels basis based on the California Air Resources Board GREET model.

Hydrogen supplied to fuel cell vehicles is among the lowest carbon fuels available for use as transportation fuel. The total carbon reduction potential from the Emeryville Hydrogen Refueling Station is significant due to its 350 kg per day compressor nameplate capacity.

As of October 2018, the Emeryville Hydrogen Refueling Station had passed Department of Food and Agriculture/Division of Measurement Standards certification testing and received more than two original equipment manufacturers' letters of support allowing it to be declared officially open. The station is currently in the full open status and should encourage more use of the station and car sales in the area.

## 2.6 Transition to Alternative Fuels

The Emeryville Hydrogen Refueling Station displaced approximately 6,000 gallons of gas equivalent during in its first 4 months in operation. It is estimated that hundreds of people who have now seen the Messer North America, Inc. dispenser in use will be more comfortable buying an FCEV because they know where to fuel. Greater use of FCEVs by local residents, as well as local city and State government offices, will dramatically increase the awareness and transition to hydrogen as an alternative transportation fuel.

## 2.7 Sustainability Goals 20 CCR Section 3101.5

This station's design and operation comply with the Energy Commission's Program Opportunity Notice requirements and support 20 CCR Section 3101.5. The goal of 20 CCR Section 3101.5 is to ensure that funded projects promote sustainable alternative fuels and vehicles by reducing greenhouse gas emissions associated with California's transportation system, protecting the environment, and enhancing market and public acceptance of sustainably produced alternative and renewable fuels. The station utilization is key to ensuring financial viability of the station and continued development of future stations for all station developers. A rapid increase in utilization of new FCEV will be an important step in the grown of the market.

## 2.8 Actual vs. Proposed Performance

The Emeryville hydrogen filling station meets or exceeds all the minimum technical requirements from the CEC-issued solicitation PON-13-607. The minimum performance for the Emeryville  Station is as shown in Table 5, although we have demonstrated greater performance during the initial operation of the station.

**Table 5: PON-13-607 Minimum Technical Performance**

| |
|---|
| 100 kg/day Minimum capacity over a 12-hour period. |
| 350 bar (35 megapascal) and 700 bar (70 megapascal) dispensing pressures |
| Compliance with Society of Automotive Engineers-2799/J-2601/J-2719/2600 |

Source: Messer North America, Inc.

The Emeryville Hydrogen Refueling Station was estimated to see 20 kg/day in year one, ramping up to 99 kg/day in year six. This is a developing market. Messer North America, Inc. has seen a recent increasing trend in the station demand and is hopeful that 2020 can provide additional car sales and station demand. Additional stations in the area will help increase vehicles adoption and demand on the Emeryville Hydrogen Refueling Station which will improve the business case for Messer North America, Inc. to develop additional stations. Currently the station supplies, on average 40-60 kg/day, well above the predicted 20kg/day in year one.

# Chapter 3: Conclusion

Messer North America, Inc. is now operating liquid hydrogen based fueling stations to supply light duty vehicles in California  in addition to the bus vehicle fueling stations at AC Transit in Emeryville and Oakland, California. Messer North America, Inc. appreciates the support of the State of California and the entire hydrogen community to develop the hydrogen fuel market. This is a great step forward for the State of California and Messer North America, Inc. to lead the nation with hydrogen zero emissions vehicles infrastructure and technology deployment. Messer North America, Inc. is looking forward to continuing to develop the hydrogen fuel technology and market with collaboration with the State of California, stakeholders and industry leaders. The support from this project has contributed to the commercialization of the ATZ IC90 ionic compressor which is becoming the industry standard for station developers and facilitated real world verification of liquid hydrogen supply, storage and 700 bar gaseous dispensing as a valid hydrogen pathway for this market.

# GLOSSARY

CALIFORNIA ENERGY COMMISSION (CEC)—The state agency established by the Warren-Alquist State Energy Resources Conservation and Development Act in 1974 (Public Resources Code, Sections 25000 et seq.) responsible for energy policy. The Energy Commission's five major areas of responsibilities are:

Forecasting future statewide energy needs

Licensing power plants sufficient to meet those needs

Promoting energy conservation and efficiency measures

Developing renewable and alternative energy resources, including providing assistance to develop clean transportation fuels

Planning for and directing state response to energy emergencies.

FUEL CELL ELECTRIC VEHICLE (FCEV)—A zero-emission vehicle that runs on compressed hydrogen fed into a fuel cell "stack" that produces electricity to power the vehicle

KILOGRAM (kg)—The base unit of mass in the International System of Units that is equal to the mass of a prototype agreed upon by international convention and that is nearly equal to the mass of 1,000 cubic centimeters of water at the temperature of its maximum density.