

HYDROGEN & FUEL CELLS in the PORTS WORKSHOP

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CALIFORNIA HYDROGEN
BUSINESS COUNCIL



CHBC Hydrogen and Fuel Cells in the Ports Workshop Report

California Hydrogen Business Council

11/20/17

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Acknowledgements

Planning Committee

The 2017 Hydrogen and Fuel Cells in the Ports Workshop was planned and organized by members of the California Hydrogen Business Council's Goods Movement, Heavy-Duty Transportation, and Clean Ports Sector Action Group.

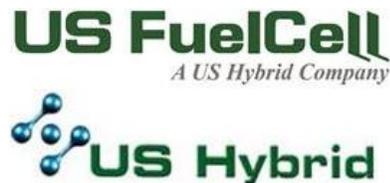
Workshop Sponsors

We thank the following organizations for their financial contribution, without which this workshop would not have been possible.

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Executive Summary

Harbors represent a vital component of U.S. infrastructure, for commerce and defense. Harbors are economic drivers for state jobs and development, entry points for goods used throughout the country, and important bases for the U.S. Navy. They also cause significant local air and greenhouse gas emissions, and the heavy duty truck fleets that move goods from ports to around the region cause problems well beyond the boundaries of the ports.

In California, the environmental footprint of ports is significant, both because of the volume of activity itself and because they tend to be located in areas that already experience heavy automobile and truck traffic, create smog, particulate matter, and ozone pollution, creating health problems and health costs.

California programs in different stages of development will have an impact on the transition to hydrogen energy systems, including the Sustainable Freight Action Plan and Clean Air Action Plans. Hydrogen and fuel cell systems will have to meet the economic and performance requirements of the terminal operators to find market acceptance in the ports.

To accomplish clean air goals with a mix of technologies, including a significant use of hydrogen, will require collaboration among hydrogen industry suppliers, the spectrum of users at the port, funding sources and regulatory agencies. In addition, since much of the pollution arises from idling or slow traffic, both zero-emission technologies and intelligent traffic management can contribute to the solution.

Key take-away messages:

1. Port managers are keenly aware of the need to reduce emissions, and the Port of Long Beach and Port of Los Angeles have recently delivered an updated Clean Air Action Plan. They are interested in the role that hydrogen and fuel cells can play. Suppliers need to work closely with the players at the ports to understand operations and to match technology solutions appropriately.
2. Commercial fuel cell and hydrogen systems exist to provide clean mobile power in many types of vehicles and stationary power for onsite operations. The technologies need to be proven in the port environment and available in industrial quantities to move into this market.
3. Funding sources with various agencies can be accessed to move hydrogen technology into the ports, and port managers are willing and welcoming for further discussion.

Key actions that follow from this workshop include this report, a webinar presenting the findings, and a follow-up workshop, to discuss implementation of the findings to develop implementation plans. Perhaps the next workshop should focus on one aspect of the ports, such as freight.

Introduction

The California Hydrogen Business Council (CHBC) hosted this one-day workshop to discuss the current hydrogen and fuel cell activities in ports and maritime, hear the needs and challenges from port and maritime customers (port authorities, terminal operators, trucking companies) of California Ports to reduce their emission footprint and meet California state air quality requirements.

This workshop is a follow up event to the 2016 Hydrogen and Fuel Cells in the Ports Workshop, held at the Port of Los Angeles. At the 2017 workshop, attendees heard updates from last year with presentations from ports authorities, terminal operators, trucking companies, hydrogen and fuel cell technology providers, and State funding agencies.

This report presents an overview of the discussion topics, along with highlights of the workshop intercourse and the order generally follows the chronology of the agenda. References to materials from the workshop and related activities are included.

Context

The purpose of the 2017 Hydrogen and Fuel Cell in the Ports Workshop was to expand the discussion from the 2016 Ports Workshop to develop an understanding of the needs and challenges of California ports, terminals and fleets, and how hydrogen fuel cells can help reduce their emissions footprint and meet California State air quality requirements.

The California Sustainable Freight Action Plan calls for freight operators to reduce emissions of criteria pollutants and greenhouse gases generated at the ports. Ports produce the highest level of toxic emissions in California and related health problems. The primary source is the exhaust from the various modes of transport (drayage, forklifts, container movers) throughout the port. On-site power generation for buildings and vessels also contributes to air emissions.

Many of these activities could be rendered pollution-free by converting to zero emission hydrogen and fuel cell powered applications. Fuel cell or fuel cell/battery hybrid applications of many types and sizes are commercially available and can replace the current fossil fuel-burning engines. Hydrogen electric power generators or other fuel cell technologies are commercially available. Educating potential users on the current products was one of the goals of this workshop.

Discussion Topics – Segments and Summaries

Welcome, Introductory Remarks and Overview

Jeff Serfass, Executive Director, California Hydrogen Business Council

The California Hydrogen Business Council has over 100 members and organizes its activities into three market areas, each with its Sector Action Group to conduct the work of the Business Council and to develop CHBC advocacy positions to build government support for hydrogen in California businesses. One of these groups, the Heavy Duty Freight, Goods Movement and Clean Freight Sector Action Group, recognized two years ago the importance of ports as sources of emissions and the many hydrogen and fuel cell solutions that could assist in reducing them. Thus was born this second CHBC ports workshop in Vallejo, the first being with the Port of Long Beach and the Port of Los Angeles in November 2016.

Thanks to our sponsors and the California Maritime Academy for hosting us. We realize that life is changing here with current leadership addressing sustainability and renewable energy.

Addressing the Shift of Energy Use in the Maritime Sector

Thomas A. Cropper, President, California State University Maritime Academy

The California State University Maritime Academy, founded in 1929 as the California Nautical School to train officers for shipping, is the only state maritime academy on the Pacific coast. The ocean is the driver of the world; it covers 70 percent of the planet, 80 percent of the world population depends on seafood, 90 percent of trade moves across the oceans, and 90 percent of internet traffic moves through cables in the ocean. Each week, \$10 billion worth of goods moves through west coast ports.

Graduates of the Maritime Academy go on to build yachts, boats, and build and repair cranes. The Maritime Academy is intent on creating global change, where renewable energy supports all aspects of the maritime industry. With a focus on the future, CSUMA wants to participate in the business aspects of clean and renewable energy, the proliferation of renewable energy across the globe, and seeks ways to incorporate clean energy technologies to make maritime cleaner, greener, and more profitable. CSUMA has developed an Energy Sustainability Master plan that goes to 2032 and has a growing interest in a sustainable microgrid for campus.

Current Hydrogen and Fuel Cell Activities in Ports and Maritime

Moderator: Ryan Storz, Assistant Professor, Department of Engineering Technology, California State University Maritime Academy

As a CSUMA graduate, Ryan started his career with General Electric, working in centralized power plants and oil refineries. Seeing issues with centralized energy, Ryan turned his focus to distributed energy systems and actively advocates for microgrids and sustainable resources into the classroom and, more broadly, the ports.

Joseph Pratt, Principal Member of the Technical Staff in the Energy Innovation Department, Sandia National Laboratory: Maritime Applications

Hydrogen offers a zero emission form of energy to the ports and maritime applications. A fuel cell electric vehicle (FCEV) uses about .5 kg/day, compared to the hundreds of kg/day a ship would require. Viking Cruise Lines has announced it is developing a 20,000 kg/day hydrogen powered cruise ship. As hydrogen is adopted in ports and maritime applications, a refueling network needs to be built to accommodate hydrogen vehicles in the ports.

Ports can offer a site for large-scale hydrogen production and distribution hub; an LH2 tanker is able to transport and store 175,000 kilograms of hydrogen. Hydrogen offers the ports a fuel that can meet efficiency and emission standards, including:

- Low sulfur fuels as already required in Emission Control Areas
 - LNG is a popular alternative to diesel today
- NO_x control is important, and LNG might not be able to meet the environmental requirements
- GHG – currently Energy Efficiency Design Index (EEDI) tightens each year
- PM – increasing focus on PM_{2.5}; EU regulation expected first

Operations costs with conventional fuels increasing sharply, all alternative fueling options are on the table. Ship operators are concerned with one factor related to fuel: cost. The feasibility of hydrogen and fuel cell technology in the ports is no longer in question; ports are now looking at how to transition technically and economically towards zero emission technology. To accelerate the transition to hydrogen in the ports, action must be taken. In 2010, Norway began pursuing zero emission boats; in 2012, the first battery electric boat was developed and in 2015, Norway decided that all boats must be 100 percent electric by 2030. The Norwegians' forward thinking must be adopted throughout the world to advance hydrogen and fuel cells in the ports.

Cory Shumaker, Project Coordinator, California Hydrogen Business Council: Ports Applications

Fuel cell projects have been pursued throughout Europe; the United Kingdom, Norway, Germany, France, and Finland are all developing fuel cell boats, ships and ferries with suppliers Hydrogenics and PowerCell. The Port of Gothenburg wants to transition to zero emission vehicles. The Port of Hamburg, which is larger than the Port of Los Angeles and Port of Long Beach combined, has developed a Clean Air Action Plan to reduce NO_x and wants to implement cold ironing for cruise ships and use LNG PowerPacks to provide power at berth for cargo vessels. In the Netherlands, the Port of Amsterdam is looking into producing hydrogen from wind and the Port of Rotterdam wants to lead the world in green technologies.

California has also developed aggressive zero emission terminal equipment goals, specifically as stated in the latest Clean Air Action Plan, going to zero emission port equipment by 2030. Ports offer an opportunity to continue development of hydrogen markets; European ports are looking to produce their own fuel. Currently, diesel offers the cheapest fuel, followed by LNG then hydrogen. Additionally, the vast majority of hydrogen production is being done using natural gas, and it will need to be produced renewably eventually.

- Right now China is ordering thousands of fuel cell engines for trucks and buses
- It may be possible to power container vessels using hydrogen and fuel cells in the future, requiring up to 60 MW of power; larger ships go the longer distances and have more volume for H₂ storage; small boats that go fast are more difficult for H₂
- Possible to use waste heat? Using it increases efficiency but it hasn't been modeled much

Voice of the Customer: Opportunities and Constraints for Hydrogen and Fuel Cells in Ports and Maritime Applications

Moderator: Jim Petrecky, Vice President of Business Development, Plug Power

Why use hydrogen in the ports? Because ports are captive fleets, hydrogen solutions are economical, they produce zero emissions and hydrogen can be an enabler for electric vehicles. Yard tractors, forklifts, top handlers, RTG cranes can all utilize hydrogen fuel cells. The current fuel, diesel, offers an efficiency of 25 percent, compared to 50 percent with hydrogen. If ports transition to hydrogen, maintenance costs will be reduced and refueling time is only 1-2 minutes. Due to the continuous use of the equipment, there will not be boil off of hydrogen fuel when stored in liquid form. The ports' defined fleets and captive space utilizing large quantities of

hydrogen, starting at the seaports, will allow expansion to other nearby applications; developing a hydrogen city. The efficiency of fuel cells will lead to fuel savings, lower maintenance, no range limitations, and quick refueling. And space used for battery charging can be repurposed for revenue generation.

Basil Wong, Manager of Utilities Administration, Port of Oakland

The Port of Oakland is a small municipal utility serving the airport, navy and army. It has four marine terminals with three terminal operators with no cruise lines or ferries. The port's top partner is China, which represents 32.4 percent of cargo throughput. The port is currently involved with a number of efforts to increase air quality by reducing diesel particulate matter. In March of 2008, the Port of Oakland adopted an air quality goal to reduce community cancer health risks from port operations by 85 percent from 2005 to 2020.

When using fuel cells on ships the refueling needs to be considered; with cold ironing it's important to have the outlets in the right location. With the biggest concern for hydrogen fuels cells being focused on infrastructure, the Port of Oakland will continue to follow the development of zero emission trucks. Shore power was a huge investment paid by grants, challenged at first by non-standardized plug.

Joe Carrillo, Regional Vice President, Northern California, SSA Marine Terminal, Port of West Sacramento

Joe recently returned from assignment in Panama where there are a lot of advancements being made. Mexico has greatly progressed with a fully automated terminal. The Port of West Sacramento is looking to use electric and zero emission vehicles and equipment wherever possible. West Sacramento now has high voltage, shore power and uses heavy duty forklifts at their port.

Hydrogen and Fuel Cell Solutions for Ports and Maritime

Moderator: Dr. Michael Mac Kinnon, Senior Scientist, National Fuel Cell Research Center

Stationary and mobile fuel cell applications are important at the ports. The Port of Long Beach has an Energy Island Initiative with the reduction of NOx emissions being a key target. Fuel cells bring high electrical efficiency among combined heat and Power (CHP) options plus reduce pollutants. Should look to tri-generation systems as well as electrolysis to produce hydrogen to meet the highly technical requirements. Rail should be part of the mix as well.

Laurence Dunn, Nuvera Hyster-Yale: Off-road port equipment (large forklifts, stackers)

Nuvera Hyster-Yale has built 300,000 lead acid, electric vehicles since 1932, which required high maintenance, dedicated ventilated charging areas, with batteries overheating after two shifts of continuous operation. Nuvera Hyster-Yale produces 100,000 vehicles per year, 25 percent of which are electric. Port operators have called Hyster-Yale looking for zero emission vehicles to meet 2030 mandates and goals. They are looking to eliminate all fossil fuel emissions at California locations where their vehicles are in use. Nuvera Hyster-Yale has developed a 52 ton fuel cell Laden prototype container handler that can perform three, 8 hour shifts.

Hyster-Yale has developed wireless charging for their electric equipment. They have encountered challenges with fuel cells; can only do 350 bar pressure and hold about 20 kg of hydrogen. The solution for delivery of hydrogen to the ports will be through pressurized hydrogen with liquid hydrogen being the way forward. The preventative factors for a 700 bar system is cost and space. Rail is a target because there is no opportunity charging.

Dr. Abas Goodarzi, President and CEO, US Hybrid: On-road vehicles (Class 8 trucks, refrigeration units)

50% of energy in transportation is wasted due to traffic. Electric drives decouple traffic issues from drive time. US Hybrid collaborated with the largest truck company in China and will be producing 1200 fuel cell engines for

the Chinese with the goal to have a truck optimized in weight to maximize payload. US Hybrid is confident that fuel cell engine cost will drop to be compatible to a diesel engine and after treatment.

Fuel Cells are enabled with fast refueling and 24/7 operation, as well as more efficient and zero emission compared to CNG. A Fuel Cell Truck was delivered to TTSI for demonstration in October 2017. Hydrogen is a safer alternative fuel compared to natural gas.

Johan Burgren, Business Manager, PowerCell Sweden AB: Fuel Cells in Maritime (Cold Ironing)

PowerCell is a spinoff of Volvo and makes stacks only. Nel partnered with Hexagon composites on a joint venture called Hyon. PowerCell has created the highest power density fuel cell stack in the world at 100 kW and will be working with Daimler, Ford, Volvo, and Volkswagen to continue stack development. A 40 feet container can fit 3 MW with the balance of plant and fuel cell stacks. They have a 100 kW fuel cell truck for Coop and are working with Kalmar forklifts using 700 bar.

Prof. Keir Moorhead, Maritime Vocational Instructor, California State University Maritime Academy: Clean Boats (ferries)

Professor Moorhead worked for Hornblower, designing hybrid vessels and his work at CMI gives him an engineering and operations orientation to hydrogen fuel cells. There are many harbor craft types that can utilize hydrogen fuel cells, including tugboat, ferries, excursion boats, workboats, patrol boats, etc. The electrification of harbor vessels is happening and opens the door for fuel cells that can be brought in where there are existing generators. Regulation by the Coast Guard is behind but they are supportive of advanced technology. In the industry, there is no technology risk acceptance for the possible risk of loss of vessel utilization with the high cost of the vessels. Moorhead would like to start developing a fuel cell marine vessel.

Morning Recap - Audience Discussion

There is an opportunity with building ships or vehicles with electric drives that have a Genset or other generator, which fuel cells could eventually replace. In the future, capturing thermal energy from fuel cells will be a focus. BMW is seeking a truck supplier as a platform to test fuel cells. The Port of Oakland must explore the possibility of producing hydrogen onsite. The business case for hydrogen production in the ports needs to be developed and addresses the permitting situation, as well as concerns from the Coast Guard.

Keynote – Safety Regulations, Codes and Standards for Hydrogen in the Ports and Maritime Environment

Jay Keller, President, Zero Carbon Energy Solutions

Laboratory testing has assessed the risks for setback for hydrogen and footprints for hydrogen fueling stations. Building a hydrogen station to NFPA standards is less risky than a conventional gas system. H2tool.org is a resource for safety tools regarding hydrogen. In 2003, the Hydrogen Safety Panel formed to ensure that safety was a consideration for every project. The safety panel is currently discussing how to recertify hydrogen tanks.

Keynote – Opportunities and Barriers to Hydrogen Infrastructure in Ports

Chris Kretz, Business Development Manager Hydrogen Fueling, Air Products and Chemicals, Inc.

Since 1993, Air Products and Chemicals has performed hydrogen fueling projects, supplying everything from hydrogen molecules to full turnkey systems. Air Products and Chemicals refuels everything from submarines to Zambonis. As part of ZECT II, they will be refueling six drayage trucks at the Port of Long Beach; 240 kg/day by trucking multiple gas trailers filled with gaseous hydrogen. With a wide variety of fuel cell applications available, the ports offer multiple customers from fueling station site owners to truck operators to port operators.

Numerous decision factors must be considered when developing projects; daily use, single dispensing point, reliability, space availability, etc. The need for each component of a station must be considered or a trailer can be used. For onsite generation of hydrogen, it is possible to have a small or large scale steam methane reformer (SMR) to convert natural gas to hydrogen. Air Products and Chemicals has had various SMRs depending on the project, often using mobile refueling. Hydrogen refueling remains to have a number of challenges but all are capable of being resolved.

Government Programs and Funding Opportunities for Hydrogen Projects in Ports and Maritime

Moderator: Karen Schkolnick, Director of Strategic Incentives Division BAAQMD

The freight sector is 1/3 of California's economy. There are numerous bills and funding authorities for light and heavy duty transportation and a lot of interest in the work force development that can take place in cleaning up this sector. Border ports of entry are key. Hydrogen's future will be dependent on available funding to accelerate development.

Leslie Goodbody, California Air Resources Board

California has power-to-shore requirements for vessels that call upon a California port 25 times per year. Emissions reductions (NOx, GHG, etc.) will be phased up from 10% reduction in 2010 to 80% reduction in 2020. A large source of emissions are from ocean going vessels; the ARB is developing regulations to treat each vessel equally, with the same requirements. ARB is currently seeking stakeholder input.

The Low Carbon Transportation Fund has awarded \$14.5 million to the Los Angeles Harbor Department, Port of LA Green Omni Terminal, to demonstrate multiple battery electric technologies with supporting charging infrastructure; the funding includes four yard-trucks, two 21-ton forklifts, a top handler, and two drayage trucks.

CARB has also funded a variety of fuel cell technology projects including the Off-Road Advanced Technology Demonstration Project solicitation, which calls for up to \$17 million for cargo handling, port and ground support equipment, and locomotive technologies and operations, with fuel cell equipment plus hydrogen infrastructure being eligible. CARB also has funding available for the On-Road Advanced Technology Demonstration Project solicitation, allocating up to \$10 million for fuel cell short and regional haul trucks.

A large amount of funds will be available in the 2017-2018 Funding Plan for clean transportation incentives; \$560 million for Low Carbon Transportation (AB 134), \$50 million for the Zero/near-Zero Emission Warehouse Program (AB 132), and \$150 million for the Advanced Freight Demonstration and Deployment Project. The Advanced Freight Demonstration and Deployment Project is meant to fund freight facilities, including warehouses, distribution centers, ports, freight airports, and railyards. Qualifying zero emission equipment includes yard trucks, delivery trucks, drayage trucks, truck refrigeration units (TRUs), cargo-handling equipment, rubber tire gantry cranes (RTGs), ground support equipment (GSE), forklifts, etc.

The ARB will conduct a workshop on October 4 to work on the funding plan. The competitive process to receive funding for projects will be done in the following order:

1. Staff releases draft funding plan and holds workshops
2. CARB Board adopts Funding Plan
3. Stakeholder Outreach:
 - Workgroup meetings
 - One-on-one meetings

- Contact sharing
- 4. Staff releases Solicitation
- 5. Team scores applications
- 6. CARB makes preliminary selections and notifies applicants
- 7. Final selections occur upon execution of grant agreements

Grantees cannot be for-profit organizations; applicant must be from nonprofit or public agency. Through heavy vehicle incentive program (HVIP), CARB offered \$300,000 for each FCEV and FC truck; and for every purchase of five buses or trucks, a \$100,000 per vehicle voucher was granted for infrastructure.

The Carl Moyer program receives \$69M/year and the local air districts select the projects; contact Anthony Fournier for additional information. The VW Mitigation Funding (Consent Decree Appendix D) applies to on-road trucks Class 4-8, off-road freight equipment, ferries/tugboats, ocean going vessel shore power and the first workshop is October 9 at CalEPA.

Larry Rillera, CEC “Update on California Sustainable Freight Action Plan and Implications for Ports”

In July 2016, the California Sustainable Freight Action plan was created to address numerous issues with emissions and freight efficiency throughout the State of California; actions 1, 3, 4, and 8 relate to heavy-duty vehicles. California passed SB1 into law on April 28, allocating \$3 billion to improve trade corridors over the next decade. Pilot projects have been identified to support the sustainable freight construct: dairy biomethane for freight, and advanced technology for truck corridors at border ports of entry. Page 14 of the Sustainable Freight Action Plan Pilot Project Work Plan: Advanced Technology for Truck Corridors lays out the number of hydrogen heavy-duty vehicles and stations targeted up to 2035. Implementation of the current action plan activities is ongoing. In July 2018, the action plan will be updated.

The CEC’s Alternative and Renewable Fuel and Vehicle Technology Program by AB 8 has extended through 2024. In March 2015, the five seaports of Hueneme, Long Beach, Los Angeles, Oakland, and San Diego formed the Ports Energy Collaborative. The CEC’s focus has been to find zero emission vehicles for every step of the freight chain.

Final Remarks – The Case for Hydrogen in Ports and Maritime

Tyson Eckerle, Deputy Director of Zero Emission Vehicle Infrastructure, Governor's Office of Business and Economic Development (GO-Biz)

The Governor’s Office of Business and Economic Development (Go-Biz) wants to place most of the focus from the executive order on freight, representing a huge part of the economy. Hydrogen offers a very promising technology to meet GHG reduction goals in the freight sector. Fuel Cells in maritime applications and vessels will be a large investment. The objective of these goals, mandates, and regulations is to make every step of the goods movement sector zero-emission in the future.

To accomplish this goal, California must implement solid feedback groups and the industry must push policy makers toward hydrogen. The CHBC will need to take on the role of bringing business and policymakers together. Industry needs to believe that there is going to be a market and the policy framework developed. When vehicle assets are pulled together to use one source of hydrogen it makes a lot of sense. Incremental change is good but we need to make transformational change, and ultimately there needs to be a pathway for businesses to make money. The State is eager to work with industry and stakeholders, and we are limited only by our imagination.

Open Discussion, Outcomes and 2018 Action Items

Moderator: Cory Shumaker, Project Coordinator, California Hydrogen Business Council

Stakeholders need to continue outreach and education efforts, encourage collaboration between policymakers and industry. The Central Valley is growing rapidly and offers opportunity in the Ports of Stockton and West Sacramento. The Port of West Sacramento has operational and new technology meetings to educate its workforce.

The Bay Area Air Quality Management District has available funding but we need to continue to bring stakeholders together. We need to utilize partners in Washington DC and organizations like the CHBC are necessary to organize and deliver the hydrogen message.

The industry needs to take advantage of funding opportunities, especially from the VW settlement.

The CHBC brings different players together that can benefit from hydrogen technology and the funding opportunities with it. However, we should also be engaging the people affected, communities and environmental groups that represent the communities and companies.

The California State University Maritime Academy is the only academy of its kind in California and one of the few in the country. We need to bring in the cadets and inform them of the issues and logistics dilemmas they will be dealing with after graduation.

The Bureau of Shipping has focused on LNG; other partners have been looking to hydrogen and fuel cells. A cadet at the meeting offered that every ship on the West Coast has at least one graduate of CSUMA; if you want people who are working the power plants or the ships, they will come through here; pursue further development through CSUMA. Elan Bond, Nel Hydrogen, offered that our industry is relatively small and we have a visibility issue; every person you talk to is an opportunity for outreach, advocacy and education; share your excitement.

Tyson Eckerle offered that this is the last year for Governor Brown's administration – make sure that hydrogen is included in any events. It is great for CHBC to collect comments for us to share with the Governor.