DISCLAIMER

The views and opinions expressed in the Hydrogen Fuel Cell and Battery Electric Vehicle Stakeholder Charrette presentations are that of specific presenters, and may not necessarily represent the position of the Hawaii Strategic Development Corporation or Hawaii State Energy Office.
U.S. DOE All Electric Vehicle Activities

Hydrogen Fuel Cell and Battery Electric Vehicle Shareholder Charrette

Pete Devlin
Manager, Market Transformation Program
U.S. Department of Energy
Fuel Cell Technologies Office

1/14/2015
All-of-the-Above Energy Strategy

Fuel Cell Technologies are included in the U.S. “all of the above” energy strategy.

“We’ve got to invest in a serious, sustained, all-of-the-above energy strategy that develops every resource available for the 21st century.”

- President Barack Obama

“As part of an all-of-the-above energy approach, fuel cell technologies are paving the way to competitiveness in the global clean energy market and to new jobs and business creation across the country.”

- Secretary Moniz, U.S. Department of Energy
EV Community Readiness Projects

- 16 projects in 24 States
- Activities included—
  - Streamlined permitting processes
  - Revised codes
  - Training emergency personnel
  - Educating the public
  - Developing incentives

“A Guide to the Lessons Learned”

- Synthesizes project findings
- Highlights key activities and outcomes
- Help readers easily connect with relevant resources

http://maui.hawaii.edu/eva/home
Partner Progress

600,000+ employees

300+ worksites
DOE provides technical assistance, a best-practice sharing forum, and recognition

electricvehicles.energy.gov

WorkplaceCharging@ee.doe.gov
“All-of-the Above” Strategic Benefit: Reduced Well-to-Wheels Petroleum Use

Analysis by Argonne National Lab, National Renewable Energy Lab and EERE (Vehicles, Fuel Cells, & Bioenergy Technologies Offices) shows benefits from a portfolio of options

Well-to-Wheels Petroleum Energy Use for 2035 Mid-Size Car (Btu per mile)

See reference for details: http://hydrogen.energy.gov/pdfs/13005_well_to_wheels_ghg_oil_ldvs.pdf

- Updated, peer-reviewed analysis (EERE multi-Office coordination)
- BEVs and FCEVs provide the greatest reductions in petroleum use.

Low/medium/high: sensitivity to uncertainties associated with projected fuel economy of vehicles and selected attributes of fuels pathways, e.g., electricity credit for biofuels, electric generation mix, etc.
Medium Duty (MD) and Heavy Duty (HD) vehicles (Classes 3-8) consume 22% of the petroleum (Source: Edison Electric Institute)


U.S. Class 3-8 vehicles (Source: R L Polk):

- 11.9 million registered vehicles
  - New vehicle sales about 600,000 units annually
- 4.2 million pre-2000 vehicles still in operation
- Diesel ICE engines dominate – 77.5 % market share March 2014
  - Diesel ICE share declining – competing technologies include gasoline engines, flex fuel vehicles, compressed natural gas, and plug-in hybrid
“Clustering” Motive Fuel Cells Can Drive Hydrogen Demand

Fuel Cell Vehicles at a Representative Port-Based Industrial Complex

- Cargo Tugger
- Containerized FC Generator
- Class 8 Drayage Truck
- Bucket Truck
- Refrigerated Truck with APU
- Terminal Tractor
- Perimeter H₂ Fueling Station (Public Access)
- Fuel Cell Bus
- LD FCEV
- MD FC Hybrid
- FC MHE
- Refrigerated Truck with APU
- Containerized FC Generator
- Class 8 Drayage Truck
- Containerized FC Generator
- Class 8 Drayage Truck
- Containerized FC Generator
- Class 8 Drayage Truck
• Data collection on thousands of vehicles and EVSEs as part of the Transportation Electrification Initiative:
  – 2.7 million LDV PHEV/EV charge events on 14,000 EVSE
  • 165,809 PHEV/EV miles and 7,646 charging events documented per day
  – 574,435 medium-duty EV miles documented for 339 trucks in commercial service
  – Testing under varied and extreme thermal conditions
  – Evaluated 13 EVSE and DCFC hardware units
• Data collected informs deployment planning:
  – Analysis of charging station utilization by venue/location
  – Effect of utility time-of-use electricity rates and fee structures on consumer charging behavior
  – Other lessons learned: PEV performance, EVSE permitting procedures, installation costs

Demonstration results, including lessons learned white papers, technical reports, summary data, and maps are publicly available: http://avt.inl.gov/
Workplace Charging Challenge

Goal: Increase the number of employers offering charging by 10x by 2018

150+ Partner employers committing to provide EVSE for employees
300+ Worksites across the country
3,000+ EVSE installed or planned for installation
17 Ambassadors promoting and supporting workplace charging

Resources: electricvehicles.energy.gov, WorkplaceCharging@ee.doe.gov
DOE-GSA Feasibility Study: Hydrogen Station in Downtown Honolulu

- 1.4-acre land area at “Fort Armstrong” site in downtown Honolulu.
- Income-producing site improvements include:
  - Hydrogen fueling station – 65 kg/day @ price competitive with gasoline and diesel
  - Covered 175-stall parking structure
  - Solar panels mounted on parking structure roof
  - Solar panels generate about 700 kW per day – used to produce hydrogen
Mission: Advance U.S. energy, economic, and environmental security by supporting local decisions to reduce petroleum use in transportation

www.afdc.energy.gov/locator/stations/
Thank You

Peter.Devlin@ee.doe.gov

Key Dates:

• FY15 SBIR Applications: February 3, 2015
• Annual Merit Review: June 8-12, 2015

hydrogenandfuelcells.energy.gov
Workplace Charging Challenge

Goal: Increase the number of employers offering charging by 10x by 2018

Partners
• Commit
• Take Action
• Share Progress

DOE
• Assist
• Connect
• Recognize

Ambassadors
• Promote
• Support
A Fuel Cell Industry Emerges

Robert Rose
Breakthrough Technologies Institute
January 14, 2015
Fuel Cell Drivers

- High efficiency
- Excellent environmental performance
- Enables other technologies
  - Good fit with renewable energy
- Profit Motive
Economic Motivation

• Jobs and profits
  – 3 million jobs (Korean government)
• Business case in niche markets
• Reliable power: Power failures cost US $18-33 billion in 2013
  – **Reliability**: Power where and when you need it
  – **Resiliency**: Running through increasingly powerful storms
  – **Power Quality**: For modern devices
  – **Security**: Against attack and natural disasters
  – **Affordability**: Predictable pricing, reasonable rates
  – **Efficiency**: Transmission, distribution, generation
  – **Safety**: For customers and workers
  – **Flexibility**: For intermittent generation and self generation
  – **Environmentally friendly**: Reduce noise, emissions

• Changing regulatory environment – focus on customer
  – Japan, NY State
Fuel Cells Fit the New Utility Paradigm

• High efficiency distributed power
  – Decentralized, close to customer

• Long run time backup power
  – Days not hours

• Support for power grid via electrolysis

• Capability to store large amounts of power
Toyota on Efficiency

Comparison of total efficiency in case of operation on the fuel originated from NG

<table>
<thead>
<tr>
<th>Fuel efficiency</th>
<th>Vehicle efficiency</th>
<th>Total efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNG</td>
<td>84%*</td>
<td>34%</td>
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<tr>
<td>CNG HV</td>
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<tr>
<td>Hydrogen</td>
<td>54%*</td>
<td>60%</td>
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<tr>
<td>FCV</td>
<td></td>
<td></td>
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<tr>
<td>Electricity</td>
<td>32%*</td>
<td>81%</td>
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<tr>
<td>EV</td>
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</tbody>
</table>

Total efficiency of Hydrogen-FCV is the highest

Toyota Corp. 2014
Oil Price Volatility: Prices

Inflation adjusted
Oil Price Volatility: Price Swings

Short term swing up to 180%
INDUSTRY SNAPSHOT
DOE Report: $1.3 Billion Industry

DOE 2013 Fuel Cell Industry Market Report
35,000 Systems Shipped, ~ 170 MW

Fuel Cell Systems Shipped
by Application, World Markets: 2008-2013

Megawatts of Fuel Cells Shipped
by Application, World Markets: 2008-2013
E4Tech 2014 Preview

- Unit shipments are up, megawatts are down
- Ene-Farm and small portable systems drive unit numbers
- Large stationary power in Korea dominates megawatt #s
RD&D Funding 2014

US: $150 M
EU: $120 M ($720 M committed to 2020)
  – Matched by industry and other European funding
Japan $600 M

Expanded support for hydrogen stations
New Japanese Energy Plan

- Minimize reliance on nuclear power
- Increase import of US shale gas/coal (short term)
- **Shift to alternative vehicle fuels, renewable generation**
- Demand management/conservation
- Develop a **new energy model**
  - Distributed energy to reduce grid dependence
  - Resiliency
  - Open access and consumer choice
- Remain committed to CO$_2$ reduction
Hydrogen Has “The Central Role”

- Energy carrier
- Residential fuel
- Vehicle fuel
- Interconnect with renewables/storage

Chiyoda Toluene Strategy

Toyota 2050 Vision
Vehicles

• 50%-70% “new generation vehicles” in new car fleet by 2030
  – Natural gas, battery and FCEV
• Toyota first sales 12/2014, announced expansion of manufacturing capacity
• Price <Land Cruiser
• Honda early 2016
• Subsidy of 2M¥
• proposed
INFRASTRUCTURE PROGRAMS COMPARED
$700 M+ Committed in 2013

- California: $100-$200M (multiyear)
- Japan: $128M (through 2015)
- Europe: $475 M (multiyear)
California H2 station progress

- 10 stations open
- 18 in development, construction or commissioning
- 28 + mobile fueler in process

[http://cafcp.org/stationmap](http://cafcp.org/stationmap)
California Funding to Date = $90 million

- 45 new stations ($72.7 million)
- 3 station upgrades ($6.7 million)
- 4 O&M grants ($1.2 million)
- 1 mobile fueler ($0.9 million)
- Other funding support
  - AC Transit Oakland station ($3 million)
  - CDFA DMS retail dispensing ($4 million)
  - UC Irvine STREET model ($1.5 million)
California Future Funding

• AB 8 signed into law by Gov. Brown
  – Extends funding for important air quality and alternative fuel programs
  – Guarantees $20M annually through 2023 if necessary to achieve 100 hydrogen stations
  – Annual survey, evaluation and reporting

• Funding increases likelihood stations will be in place to support early market FCEVs
  – Legislative reviews based on vehicle sales
Auto Industry Participating

- **Toyota**
  - $7.2 M in First Element Fuel (CA)
  - 12 Northeast Stations with Air Liquide
  - Making 5600 patents available until 2020

- **Honda**
  - $13.8 M in First element Fuel (12 stations)
H2USA

• Public-private partnership
  – DOE, Labs, Auto Industry, significant suppliers
• Working groups on stations, locations, financing, market support
• 2015: “image of vehicle volume”
• 2020: “Multiple OEMs deploying vehicles
H2FIRST

- NREL-Sandia
- Dealing with technical challenges of stations and fueling by “creating opportunities for industry partners to pool knowledge and resources”
- Goals:
  - reduce the cost and time of fueling station construction,
  - increase station availability,
  - improve reliability
Japan H2 Station Status

- 31 stations through 2014
- Shift to commercial partners
- 15 demonstration stations stay open

- 100 by 2015
- 2500 by 2025
- 5 million vehicles

*This map is made by HySUT, and each point on the map does not show the exact site of HRS.*
**European H2-Station Status**

~ 30 in 2014

<table>
<thead>
<tr>
<th>Country</th>
<th>Status</th>
<th>Planned Until</th>
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</thead>
<tbody>
<tr>
<td><strong>UK</strong></td>
<td>4 existing</td>
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<td></td>
<td>1 planned in 2014</td>
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<td></td>
<td>UK H₂ Mobility:</td>
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<td></td>
<td>- 65 HRS until 2020</td>
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<tr>
<td></td>
<td>- 330 HRS until 2025</td>
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<tr>
<td><strong>Netherlands</strong></td>
<td>1 existing</td>
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<td></td>
<td>3 planned until 2015</td>
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<td></td>
<td>HIT-I and HIT-II</td>
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<td></td>
<td>H₂ Mobility NL:</td>
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<tr>
<td></td>
<td>- 30 HRS until 2017</td>
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<tr>
<td><strong>France</strong></td>
<td>HIT-I Partner</td>
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<td></td>
<td>France H₂ Mobility:</td>
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<td></td>
<td>- ~150 HRS until 2020</td>
<td>estimation</td>
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<tr>
<td><strong>Germany</strong></td>
<td>50 HRS until 2015</td>
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<td></td>
<td>H₂ Mobility:</td>
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<td></td>
<td>- 400 HRS until 2023</td>
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<tr>
<td><strong>Sweden</strong></td>
<td>1 existing</td>
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<td></td>
<td>5 planned until 2016</td>
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<td></td>
<td>HIT-I and HIT-II</td>
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<tr>
<td><strong>Norway</strong></td>
<td>6 Existing</td>
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<tr>
<td><strong>Denmark</strong></td>
<td>2 existing</td>
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<td></td>
<td>HIT-I and HIT-II</td>
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<tr>
<td><strong>Scandinavia</strong></td>
<td>SHHP</td>
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<td></td>
<td>- 45 HRS until 2015</td>
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</tbody>
</table>
50 HRS for Germany

- Joint Letter of Intent to expand German network
- Targets 100 by 2017, 400 by 2023
- €350 M investment
- Current Status:
  - Location planning finalized
  - Applications in for 23 stations
Final Thoughts

• In Japan industry push -> government cooperation
• Europe evolved model similar to Japan
• Involvement from gasoline retailers
• In U.S., government push in California

• Credits: CAFCP, HySUT, NOW
Eileen Wenger Tutt
Executive Director
CA Electric Transportation Coalition
Air Agency Leadership/Imperative

Context: CA – some of the worst air quality in the nation – challenge to meet NAAQS

- Transportation is biggest emitter
- To meet NAAQS in California by 2050 need 100% of new light duty vehicles to be ZEV by 2040 (2025 in South Coast)
- CARB ZEV Program Leadership
Governor’s Support

Executive Order (B-16-2012)
- Directed California to work towards:
  - 1 million ZEVs by 2020
  - 1.5 million ZEVs by 2025
  - Transport related GHG’s 80% below 1990 by 2050

- **118,505 ZEV sold in CA in 2014**

- **2015 Inaugural Address: 50% Petroleum reduction by 2030**

- Reduce GHGs 80% by 2050 (Executive Order S-3-05)
Legislative Support


**Up to $150 Million in Annual State Funding**
- California Energy Commission =$100 million/year
  - $20M/year for H2
- CARB = $50 million/year

**AB 32 (2006)** – Reduce emissions to 1990 levels by 2020 (about 15% compared to BAU)
  - defended by voters in 2010
Automaker Support – PEV and FCEV
Public/Private Coordination
Hydrogen Station Economics

Hydrogen Network Investment Plan
Energy Independence Now
www.einow.org
Station Developers Face Significant Marketplace Uncertainty

2010 OEM Surveys

¼ ZEV Likely Compliance

Credit: Energy Independence Now
Capital Cost Share Can Help Enable Economically Viable Stations

Core Market, ZEV Likely Compliance, $2m 500kg/day Delivered Gas Station, Built in 2015:

Better for Consumer  Better for Station Provider

<table>
<thead>
<tr>
<th>Capital Expense of Station</th>
<th>Govt. (70%)</th>
<th>Private</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1,000k</td>
<td>-0.8%</td>
<td>14.0%</td>
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<tr>
<td>$1,100k</td>
<td>-2.0%</td>
<td>12.8%</td>
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<td>$1,200k</td>
<td>-3.0%</td>
<td>11.6%</td>
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<td>$1,300k</td>
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<td>0.4%</td>
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</table>

*O&M Support not Included

Credit: Energy Independence Now

<table>
<thead>
<tr>
<th>IRR of a 2015 Core Market: 500-DH2 Station</th>
<th>Vehicle Sale / Likely Compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>If long term Hydrogen Retail Price:</td>
<td></td>
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<tr>
<td>$8.00</td>
<td>$8.50</td>
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<tr>
<td>$1,000k</td>
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</table>
...But not if market adoption is slow

Core Market, **Quarter ZEV**, $2m 500kg/day Delivered Gas Station, Built in 2015:

<table>
<thead>
<tr>
<th>Cost Share</th>
<th>Better for Consumer</th>
<th>Better for Station Provider</th>
</tr>
</thead>
<tbody>
<tr>
<td>Govt. (70%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital Expense of Station</td>
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<tr>
<td>$1,000k</td>
<td>-20.5%</td>
<td>16.7%</td>
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<td>-20.8%</td>
<td>15.8%</td>
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*O&M Support not Included

Credit: Energy Independence Now
Market Assurance Grants (O&M) can buffer against slow rollout

Core Market, **Quarter ZEV**, $2m 500kg/day Delivered Gas Station, Built in 2015:

<table>
<thead>
<tr>
<th>Capital Expense of Station</th>
<th>Private Cost Share</th>
<th>Govt. (70%)</th>
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<tbody>
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<tr>
<td>$2,400k</td>
<td>-17.2%</td>
<td>-6.9%</td>
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</table>

Better for Consumer

Better for Station Provider

*Add Market Assurance Grant (e.g. O&M Support)*

**Credit: Energy Independence Now**
CEC’s Strong Solicitation

Offer (PON 13-607):

- Up to 85% of Capital Cost (90% for Renewable)
- Up to $100K/year for 3 years for O&M
  - Funding contingent on station operational date

Response:

- 28 Stations & 1 Mobile Fueler Awarded
- 32 other stations with passing scores
  - $46.6M awarded, $103M requested
A to do list from 2013 (EIN):

- Continue to offer attractive ZEV credits
- Subsidize early FCEVs (CVRP)

Building Market Confidence:
- Secure long term funding (AB8)
- Offer attractive cost share
- Offer O&M Support
- Streamline grant process (Flexibility, rewarding fast deployment, permit support)

Automakers

+ A commitment mechanism
  - Toyota/First Element

Station Developers

Credit: Energy Independence Now
Translating to Hawaii

California has gone to great lengths to start the market - our goal is for everyone to benefit from this
  ◦ Sharing lessons learned, driving down costs, building supply chain/experience

Ingredients for FCEV success in Hawaii
  ◦ Strong Leadership/Champions – from Govt. and/or Industry
  ◦ Strong Support – from Govt. and Industry
  ◦ Funding (public and/or private) to enable stations to succeed until H2 sales take over
California H2 – still work to do

- High Level Attention – monthly H2 Policy Meetings

- Working closely with DOE – C&S, station commissioning, H2USA, etc.

- Every step uncovers new challenges – we hope to help other jurisdictions plan/learn from our efforts
## Supporting Station Permitting

- Community Outreach & Response
- Tracking & Troubleshooting

<table>
<thead>
<tr>
<th>Last Updated</th>
<th>Permit Status</th>
<th>Station &amp; Task Name</th>
<th>Who has the ball?</th>
<th>Project Capacity (kg/day)</th>
<th>Str Developer</th>
<th>Address</th>
<th>Start Date</th>
<th>Estimated Operation Date</th>
<th>Station Deadline</th>
<th>Progress Status</th>
<th>Permit Visual</th>
<th>Comments</th>
<th>Commissioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/28/14</td>
<td>Permit to Build*</td>
<td>Diamond Bar - SCAQMD</td>
<td>Station Developer</td>
<td>180</td>
<td>Air Products</td>
<td>21866 E. Copley Drive, Diamond Bar, CA 91765</td>
<td>06/02/10</td>
<td>12/01/14</td>
<td>Commissioning</td>
<td>Commissioning process has resumed in earnest. Assuming all proceeds as expected, commissioning expected to be complete in November.</td>
<td>63%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10/28/14</td>
<td>Permit - Submitted</td>
<td>Irvine - UCI (upgrade)</td>
<td>Station Developer</td>
<td>180</td>
<td>Air Products</td>
<td>19172 Jamboree Rd, Irvine, CA 92612</td>
<td>06/02/10</td>
<td>01/30/15</td>
<td>Permit Submitted</td>
<td>Addressing final comments. Key challenge remaining is power supply approach. UCI has changed its requirements - both parties working toward a resolution.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10/28/14</td>
<td>Permit - Submitted</td>
<td>Irvine - Walnut Ave.</td>
<td>Station Developer</td>
<td>180</td>
<td>Air Products</td>
<td>5410 Walnut Ave, Irvine, CA 92614</td>
<td>06/02/10</td>
<td>12/31/14</td>
<td>Permit Submitted</td>
<td>Received full comment package back from City on 10/7/14. Developer working the response, expect to re-submit early November. Review uncovered a planning issue - the project will require a CUP. This is a 3-4 month process.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10/28/14</td>
<td>Design</td>
<td>Lawndale - Inglewood Ave.</td>
<td>Station Developer</td>
<td>180</td>
<td>Air Products</td>
<td>15606 Inglewood Ave, Lawndale, CA 90260</td>
<td>06/02/10</td>
<td>12/31/14</td>
<td>Design</td>
<td>Detailed Site Plan in process. On target for early November submittal to City.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10/20/14</td>
<td>Permit Submitted</td>
<td>Los Angeles - Beverly Blvd</td>
<td>City/County</td>
<td>180</td>
<td>Air Products</td>
<td>7751 Beverly Blvd, Los Angeles, CA 90036</td>
<td>06/02/10</td>
<td>12/31/14</td>
<td>Permit Submitted</td>
<td>Fire, Electrical have been approved. Building is ready to issue once real estate documentation is buttoned up (the site’s old documentation needs to be updated - a minor issue)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10/29/14</td>
<td>Under Construction</td>
<td>Los Angeles - West LA 2</td>
<td>Station Developer</td>
<td>180</td>
<td>Air Products</td>
<td>11261 Santa Monica Blvd, Los Angeles, CA 90025</td>
<td>06/02/10</td>
<td>01/20/15</td>
<td>Under Construction</td>
<td>Construction has begun (Contractor onsite October 20th). Tetronic took over week</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
• **California Fire Code**
  • Adopted NFPA 2 (2011 Version) in 2014 (effective 2015)
  • Being put to use in the field now

• **CA Permitting Guidebook**
  • Incorporating Public Comments
  • Next draft by March 2015 (living document)
  • Feed into H2USA and other State efforts
California’s New 2014 Accuracy Classes* and Tolerances for Hydrogen Fuel

<table>
<thead>
<tr>
<th>Accuracy Class</th>
<th>Acceptance Tolerance</th>
<th>Maintenance Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0</td>
<td>1.5%</td>
<td>2.0%</td>
</tr>
<tr>
<td>3.0 installed before 2020*</td>
<td>2.0%</td>
<td>3.0%</td>
</tr>
<tr>
<td>5.0 installed before 2020*</td>
<td>4.0%</td>
<td>5.0%</td>
</tr>
<tr>
<td>10.0 installed before 2018*</td>
<td>5.0%</td>
<td>10.0%</td>
</tr>
</tbody>
</table>

* No new installations after the end of the designated calendar year unless regulations are further amended. Existing installations allowed to operate until decommissioned.
Thank You

Tyson Eckerle
ZEV Infrastructure Project Manager
tyson.eckerle@gov.ca.gov
916-322-0563
ZERO-EMISSION BUSES
Prospects, Challenges, and Policy Directives

Jaimie Levin, Sr. Project Manager
BAY AREA TRANSIT MARKET SHARE

Source: SF Bay Area MTC
## TRAVEL-TO-WORK MARKET SHARE

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>New York/Northern NJ/Long Island</td>
<td>24.9%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chicago/Gary/Kenosha</td>
<td>11.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>San Francisco/Oakland/San Jose</strong></td>
<td><strong>9.5%</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Washington/Baltimore</td>
<td>9.4%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boston/Worcester/Lawrence</td>
<td>9.0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Philadelphia/Wilmington/Atlantic City</td>
<td>8.7%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Honolulu</td>
<td>8.3%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seattle/Tacoma/Bremerton</td>
<td>6.8%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pittsburgh</td>
<td>6.2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portland/Salem</td>
<td>5.7%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**California - Transit Share**

5.1%

**California - Drive Alone Share**

71.8%

**United States - Transit Share**

4.7% 5.3% -0.5%

**United States - Drive Alone Share**

75.7% 73.2% 2.5%

Source: U.S. Census Journey to Work: 2000
ABOUT CTE

Center for Transportation and the Environment

• Nonprofit 501(3)(c)
• Atlanta, Berkeley, Los Angeles
• Facilitate funding and management of research, development, demonstration, and deployment of alternative fuel and advanced vehicle technology projects
• Federal Transit Administration, Departments of Energy, Defense, & Interior, NASA, EPA, CEC, SCAQMD . . .
CALIFORNIA PROJECTS

• AC Transit FCB Support
• Long Beach BEB Procurement
• UPS FC Truck Conversion
• NorthCAT: Alt. Fuels and Advanced Vehicles Technologies Center
• Light-Duty H₂ Fueling Stations
• SCAQMD ZE Drayage Truck
TECHNOLOGY OVERVIEW
ZERO-EMISSION BUSES

BEB
Depot Charge
• Overnight
• Battery Swap

BEB
On Route Charge
• Conductive
• Inductive

Hydrogen Fuel Cell Bus
• Fuel Cell Power
• Central Fueling

Combination
Depot Charge with On Route Opportunity charging as needed
## BENEFITS OF ELECTRIC DRIVE

<table>
<thead>
<tr>
<th>Potential Benefits</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissions Reduction</td>
<td>Criteria and GHG</td>
</tr>
<tr>
<td>Performance</td>
<td>Smooth acceleration and regenerative braking; better handling and ride</td>
</tr>
<tr>
<td>Noise Reduction</td>
<td>Quiet internal and external operation</td>
</tr>
<tr>
<td>Maintenance Costs</td>
<td>Electric-drive simplicity, reliability, and durability</td>
</tr>
<tr>
<td>Energy Efficiency</td>
<td>Batteries (90%) and Fuel Cells (60%)</td>
</tr>
<tr>
<td>Clean Technology</td>
<td>No carbon-based emissions or toxicity</td>
</tr>
<tr>
<td>Total Cost of Ownership (TCO)</td>
<td>Reduced costs over life of vehicle</td>
</tr>
</tbody>
</table>
# BENEFITS OF FUEL CELL ELECTRIC BUSES

<table>
<thead>
<tr>
<th>Potential Benefits</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Emissions Reduction (W-T-W)</strong></td>
<td>Criteria (near 100%) and GHG (43% to 100%)</td>
</tr>
<tr>
<td>Clean Technology</td>
<td>No toxicity</td>
</tr>
<tr>
<td>Performance</td>
<td>Smooth acceleration and regenerative braking; better handling and ride</td>
</tr>
<tr>
<td>Noise Reduction</td>
<td>Quiet internal and external operation</td>
</tr>
<tr>
<td><strong>Deployment Flexibility</strong></td>
<td>“Range Independence” Striving for Standardization</td>
</tr>
<tr>
<td>Maintenance Costs</td>
<td>Electric-drive simplicity, reliability, and durability</td>
</tr>
<tr>
<td>Fuel Economy</td>
<td>80% to 2X better than diesel</td>
</tr>
<tr>
<td>Total Cost of Ownership (TCO)</td>
<td>Reduced costs over life of vehicle</td>
</tr>
</tbody>
</table>
FUEL CELL BUS PERFORMANCE

• AC Transit (12 Buses since 2011)
  – Lead FC: 18,300 hours (4,000 to 6,000 hours)
  – 1 million miles (1/3/2015)
  – 166 to 178 miles/day (3,300 to 4,000 mi/mo)
  – Lead Bus: 98,000 miles; 41,000 mi 2014
  – Availability >85%
  – Reliability > 15,000 miles per Roadcall
  – Five Stations: > 200,000 kilograms

• BAE Systems – Buy America Compliant
  – 3 Buses at SunLine, Lead Bus: 90,000 miles
  – Seven Buses in Production (SunLine, Boston, Michigan, New York, and Ohio)
  – Performance meets End-user Expectations
## Challenges

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Costs</td>
<td>Significant marginal costs for vehicles and Infrastructure</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>BEB: Standardization FCEV: Scalability</td>
</tr>
<tr>
<td>TCO – Risk Avoidance</td>
<td>Risk associated with costly component replacements for Emerging Technologies</td>
</tr>
<tr>
<td>Availability/Reliability/Utilization</td>
<td>Emerging Technology: “Performance Sustainability”</td>
</tr>
<tr>
<td>Maintenance Costs</td>
<td>Expected reductions have yet to be realized over time</td>
</tr>
<tr>
<td>Fuel Costs</td>
<td>Demand charges and cost of hydrogen</td>
</tr>
<tr>
<td>Scalability</td>
<td>Expanded fleets of 50, 100, or more</td>
</tr>
<tr>
<td>Deployment Flexibility</td>
<td>Range and fleet standardization</td>
</tr>
</tbody>
</table>
SURVIVING THE VALLEY OF DEATH
Toyota HINO Next-Gen FCEB

New Toyota, Hino Fuel Cell Bus to Service Route in Toyota City

Toyota City, Japan—January 8, 2015—Toyota Motor Corporation and Hino Motors, Ltd. have developed a new Toyota Fuel Cell System-equipped bus, which is scheduled to service the Toyota Oiden bus route in Toyota City from January 9.

The Toyota Fuel Cell System, which makes this bus possible, is a fuel cell system that produces electricity from hydrogen fuel. It is so clean that it is essentially a zero-emission vehicle. The system is designed to be compatible with existing infrastructure, so it can be used on regular routes in public service, including within Toyota City.

The verification testing will be conducted in real-world conditions involving live testing. The route selected is one that includes the Nishi-Gunba District, Toyota East Loop, and Toyota East Loop (between Toyota City and Mikawa Toyota Station).

The new Toyota and Hino Fuel Cell Buses are equipped with the Toyota Mirai System, which is expected to be a zero-emission vehicle for the city.

New Flyer

$900,000 FCEB – 40 Buses

May 28, 2014

Dear Mr. White,

In recent discussions with Janice Lani of the Pollution Control and the Environment (CCF), and Jeff Dray, Standard Power Systems, Inc. It came to my attention that CCF was working on the development of a fuel cell bus price target under $1 million for 40 buses. I’d like to share this information with you and your team.

The new Toyota and Hino Fuel Cell Buses are expected to service the Toyota Oiden bus route in Toyota City.

CARB $200 Million/Yr Cap and Trade

CARB $200 Million/Yr Cap and Trade

Zero-Emission Policy Commitment

500 – 1000 ZEB 2020

JOINT Press Release, 12th November 2014 12:15

European bus manufacturers and leading mayors step up for fuel cell electric buses

The Toyota Mirai fuel cell bus service route in Toyota City.

The new Toyota, Hino Fuel Cell Bus to Service Route in Toyota City.
• Substantial Investment by FTA and California ($45 million)
• Bus Models and Fueling Infrastructure are Working Well
• Supplier Investments
  – BAE Systems/El Dorado 40' Bus
  – New Flyer 60' Articulated Bus
  – Fuel Cell Suppliers: Ballard, U.S. Hybrid, Hydrogenics
  – Industrial Gas Companies (AL, AP, Linde)
• Leveraging Core Product: Series Hybrid, All-Electric Drive
• Increasing Volume Production – Buses and Fuel Supply
• Building A Supply Chain
• Sustained Funding in Support of Larger Fleets (CARROT)
• Regulatory Impetus (STICK)
INTERNATIONAL FUEL CELL BUS WORKSHOP
SUNLINE TRANSIT – FEBRUARY 25-26TH

SAVE THE DATE
FEBRUARY 25-26th 2015

INTERNATIONAL FUEL CELL BUS WORKSHOP
@SunLine Transit, Thousand Palms, CA

JOIN GLOBAL LEADERS FROM:
- EU FUEL CELLS & HYDROGEN JU
- US DEPARTMENT OF TRANSPORTATION
- US DEPARTMENT OF ENERGY
- GERMAN FEDERAL MINISTRY OF TRANSPORT & DIGITAL INFRASTRUCTURE
- GERMAN NATIONAL ORGANISATION HYDROGEN & FUEL CELL (NOW)

PLENARY & WORKING GROUPS:
- Technical Milestones
- Fleet Operation Updates
- Infrastructure Rollouts
- Market Roadmaps
- Cost & Performance Targets

Agenda details to come! Workshop contact: Lauren@cte.tv
Power your fleet with US Hybrid’s powertrain components to provide cleaner, quieter, and lower cost operation.
<table>
<thead>
<tr>
<th>Company</th>
<th>Headquarters</th>
<th>Year Established</th>
<th>Core Competency</th>
</tr>
</thead>
<tbody>
<tr>
<td>US Hybrid</td>
<td>Torrance, CA</td>
<td>1999</td>
<td>Electric Powertrain for Electric, Hybrid and Fuel Cell Heavy Duty Vehicles</td>
</tr>
<tr>
<td>US FuelCell</td>
<td>South Windsor, CT</td>
<td>2013</td>
<td>Fuel Cell Power Plant</td>
</tr>
<tr>
<td>Magmotor Corporation</td>
<td>Worcester, MA</td>
<td>1876 (Acquired</td>
<td>Servo Motors and Drives Automation, Robotic and Semiconductor Mfg.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>by US Hybrid in 2008)</td>
<td></td>
</tr>
</tbody>
</table>

** Websites: **

- [www.ushybrid.com](http://www.ushybrid.com)
- [www.usfuelcell.com](http://www.usfuelcell.com)
- [www.magmotor.com](http://www.magmotor.com)
US Hybrid’s Business Focus is Powertrain for Commercial Vehicles

Class 6
Category: Medium
Weight Range (GVWR): 19,501-26,000
Examples: Shuttle Bus, Municipalities, Monorail

Class 7
Category: Heavy
Weight Range (GVWR): 26,001-33,000
Examples: Delivery, Constructions, Agriculture, Mining

Class 8
Category: Heavy
Weight Range (GVWR): >33,000
Examples: Transit Bus, Drayage, Refuse, Sao Paulo Brazil, KL Malaysia, Mumbai, India

US Hybrid’s Business Focus is; Heavy Duty Commercial Vehicles
Core Competency: Electric Powertrain Production

DC-DC Converters

- 320kW
- 240kW
- 200kW

Input Current A

Output Power kW

- Frame and Enclosure
- Electrical/Control System
- Thermal Management System
- Fuel Processing System
- Air Processing System
- Cell Stack Assemblies
More than 50% of energy is wasted due to traffic
More than 50% of energy is wasted due to traffic

GVWR
1,800 kg

Stop/Go (Traffic)  Constant

Energy (kWh)

Drive Cycle: Ave Speed:
UDDS  US06  J45
32 kph  80 kph  23 kph
20 mph  50 mph  14 mph

GVWR
910 kg

Stop/Go (Traffic)  Constant

Energy (kWh)

Drive Cycle: Ave Speed:
UDDS  US06  J45
32 kph  80 kph  23 kph
20 mph  50 mph  14 mph
• Diesel: 37.1 kWh/gal (Energy content),
• Gasoline: 32.9 kWh/gal, (Energy content),
• Hydrogen: 39.7 kWh/kg, (Energy content),

(1kg H2 = 11 gal @ 5000 psi, same as 2 gal of diesel fuel)

- Engine Output: 4.5 kWh/kg
- Engine Output: 2.8 kWh/kg
- FC Engine Output: 15 kWh/kg

Energy Storage Density:
- Lead Acid: 0.025 kWh/Kg
- NiMh: 0.06 kWh/Kg
- Li-Ion: 0.11 kWh/Kg

- Zero Tail Pipe Emission
- Most Efficient Engine

1kg of H2 (7 miles/kg) > 2-Gallons Diesel (3.8 mpg) 40’ Transit Bus
1kg of H2 (12 miles/kg) > 2.5-Gallons Gasoline (5 mpg) Shuttle Bus
<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Driveline Config.</th>
<th>Energy Efficiency % Well to wheel</th>
<th>Fuel Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>FC vs. CNG</td>
<td></td>
</tr>
<tr>
<td>Transit Bus</td>
<td>Diesel</td>
<td>27%</td>
<td>12%</td>
</tr>
<tr>
<td></td>
<td>Hybrid</td>
<td>32%</td>
<td>H₂</td>
</tr>
<tr>
<td></td>
<td>CNG</td>
<td>26%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Electric</td>
<td>30%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fuel Cell</td>
<td>39%</td>
<td></td>
</tr>
<tr>
<td>Shuttle Bus</td>
<td>Diesel</td>
<td>27%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hybrid</td>
<td>32%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CNG</td>
<td>26%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Electric</td>
<td>30%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fuel Cell</td>
<td>39%</td>
<td></td>
</tr>
<tr>
<td>Drayage Truck</td>
<td>Diesel</td>
<td>22%</td>
<td>13%</td>
</tr>
<tr>
<td></td>
<td>Hybrid</td>
<td>27%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CNG</td>
<td>22%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Electric</td>
<td>27%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fuel Cell</td>
<td>39%</td>
<td></td>
</tr>
<tr>
<td>Refuse Truck</td>
<td>Diesel</td>
<td>23%</td>
<td>16%</td>
</tr>
<tr>
<td></td>
<td>Hybrid</td>
<td>28%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CNG</td>
<td>23%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Electric</td>
<td>27%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fuel Cell</td>
<td>39%</td>
<td></td>
</tr>
<tr>
<td>Street Sweeper</td>
<td>Diesel</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hybrid</td>
<td>29%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CNG</td>
<td>24%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Electric</td>
<td>28%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fuel Cell</td>
<td>39%</td>
<td></td>
</tr>
</tbody>
</table>
FC Powertrain Economic for Commercial Vehicles

**40’ Transit & Drayage Truck**

FCPP Breakeven ($5/Gal Diesel, 40k miles/year)

- FCPP $/kW
  - $3,000
  - $2,000
  - $1,500
  - $1,000

- Miles vs Years
- 2014, 2016, 2020

**Shuttle Bus & Delivery Trucks**

Fuel Cell Breakeven ($4.5/Gal Gasoline)

- Dollars per Kg
- $8/gal, $6/gal, $4/kg, $2/kg

- Years vs Miles
- 2014, 2016, 2020

**Fuel Cost per Mile**

- Cost ($/mile)
- $5/gal, $6/gal, $8/kg, $6/kg, $4/kg, $2/kg

- Diesel, H2

**FCPP Breakeven ROI** ($4.5/Gal Gasoline, 20k miles/year)

- FCPP $/kW
  - $3,000
  - $2,000
  - $1,500
  - $1,000

- Years vs H2 Cost ($/kg)
- 2014, 2016, 2020

100kW FCPP, price amortized

US Hybrid ©
Fuel Cell Engine Proven Reliable for Transit Bus Fleet

- Current leader 18,300+ hrs., zero stack failure (Dec 2014)
- Total fleet hrs. = 126,900+ hrs. (12 power plants)
- Exceeded DOE lifetime target of 18,000 hrs. and 25,000 hrs. life is achievable
- Implemented Preventative Maintenance Program to Extend Life
Thank you!
Breakout Session 1: Hydrogen

Moderators
Mitch Ewan
HNEI
Hydrogen Systems Program Manager

Stan Osserman
HCATT
Executive Director
Objective

Discuss feasibility of implementing hydrogen infrastructure across the State of Hawaii
Background
Renewable Fuels Pathways (simplified)

Renewable Energy Sources

Biomass
- MSW
- BioGas/LNG

Wind

Solar

Geothermal

Hydro

Wave

Feedstock

Thermolysis

Hydrotreating & Gasification

Liquid Fuels

Hydro

Conversion

Fuels

End Use

Electric Vehicles

Aviation

Ground Transportation

Ground Transportation

HI Ground Transportation ~ 500 million gpy
Primary Resource Needs (H2-FC)

• Biomass to Hydrogen
  • Sustainable growth at 20 dry tons per acre
  • Hydrogen yield, 70 kg/dry ton (NREL)

• Electricity to Hydrogen
  • 36kw-hr/kg thermodynamic limit
  • 60% efficient to compressed H2

• Assume H2-FC vehicles 2x efficiency of current vehicle fleet.

• Displacement of 20% of ground transportation fuel
  • 100 million gal liquid fuel ~ 50 million kg H2
  • 35,000 acres “good” agricultural land (dedicated HC&S), or
  • 3000 GW-hrs/yr of electricity (~30% of current state electrical generation)

Scale of need requires portfolio of solutions
Scale Introduces Many Challenges

✓ Resources - land use issues - competing use of resources e.g. electricity vs fuel, food vs fuel, etc.
✓ Political will - supportive policy (HCEI)
✓ Community support - permitting (DBEDT)
✓ Financing – strategic partners
✓ Technologies constantly changing/improving
  ➢ Strategic projects to validate viability
  ➢ Energy infrastructure is very capital intensive
  ➢ “Almost There” is not sufficient to attract private investment, complicates planning process
Role of Demonstration Projects

- Validate performance and durability of emerging technology in real world environments
- Identify areas for focused, high impact research by government and private industry
- Address/develop appropriate codes and standards
- Familiarize community with technology
- Demonstrate safety of systems
- Inform legal and insurance industries
- Help policy makers to make informed decisions

Significant efforts underway, programs becoming more focused, alternative technologies such as hydrogen, looking promising, but much to be done to get to commercial scale – resource availability becomes key.
Strategic Focus for Hawaii (H2)

✓ Demonstrate cost effective infrastructure to produce, distribute, and dispense hydrogen;
✓ Focus on fleet vehicles starting with public transportation & county trucks;
   ➢ Central fueling - 30 kg per day per bus;
   ➢ Public benefit - tax dollars support public transportation needs;
✓ Industry will take care of the vehicles;
✓ Support early heavy users of hydrogen to develop a hydrogen market;
✓ Private industry will take over when it sees it can make money.
Building Blocks for Infrastructure Development

1. Policies & Plans
2. Resources
3. Political Will
4. Strategic Projects
5. Community Support
6. Strategic Partners

We are addressing all 6 of these in Hawaii!
POLICIES & PLANS

It is Hawaii State Policy to Establish a Hawaii Hydrogen Economy
Transition Hawaii to a renewable hydrogen economy by:

- Conducting strategic R&D, testing & deployment of renewable hydrogen technologies to make informed decisions;
- Conducting engineering & economic evaluations & near-term project opportunities;
- Conducting electric grid reliability & security projects to increase penetration of renewable energy on Big Island;
- Conducting hydrogen demonstration projects including infrastructure, storage, refueling hydrogen vehicles;
- Promoting Hawaii renewable hydrogen resources to potential partners & investors.
Hawaii Clean Energy Initiative (HCEI)

Most Aggressive Clean Energy Goals in the United States

40% RENEWABLE

+ 30% EFFICIENCY

= 70% CLEAN ENERGY

Hydrogen for transportation and grid support could make an important contribution to meeting HCEI goals.

Hawaii’s sun, wind, land & sea resources can provide limitless amounts of hydrogen – forever!

Strong Support from US DOE
Resources
Hydrogen Investment Capital Special Fund (HRS 211F-5.7)

✓ Objectives:
  ➢ Provide seed capital and venture capital for private and federal projects for research, development, & testing;
  ➢ Implement the Hawaii Renewable Hydrogen Program;
  ➢ Any other purpose deemed necessary to carry out the purposes of the Hawaii Renewable Hydrogen Program.

✓ Sources of Funds
  ➢ Appropriations made by the legislature;
  ➢ Contributions from public or private partners;
  ➢ All interest earned on or accrued to moneys deposited in the special fund.
Barrel Tax (HRS 243-3.5)

- Enacted in 2010
- $1.05 per barrel of oil excluding air transportation;
- Generates ~$27 million per year;
- 60% goes to General Fund;
- 40% goes to:
  - Oil Spill emergency clean-up fund
  - State energy office
  - State Department of Agriculture
  - Energy Systems Development Special Fund (HNEI)
- Hydrogen projects have received funding from HNEI allocation;
- Potential source for Hydrogen Fund replenishment.

Need to make a compelling case
Political Will

Consistent Long-Term Political, Policy, and Financial Support
Hydrogen Program Needs to be Cost Effective

- Program needs to be seen as providing cost effective solutions/benefits:
  - What problems can hydrogen fix?
  - Is it affordable?
- Competing for scarce resources:
  - Long term vs. short term;
  - Do we fund hydrogen or air conditioners for schools? The kids are suffering today!
- Need success stories;
  - Technology validated;
  - Affordable.
- Need champions.
Must Keep Community Informed

✓ Need to justify investment of taxpayer dollars to the taxpayer;
✓ Public needs to see an immediate benefit to them:
   ➢ Public transportation vs. perception of supporting “rich man’s toys”;
   ➢ Leverage public infrastructure for private transportation for early adopters.
✓ Workforce development for the new jobs created;
✓ First Responder training. Helps address safety concerns;
✓ Legal and insurance industries need to be educated;
✓ Active public outreach campaign
Projects Need to be Strategic

Need to demonstrate the economic viability and benefits of the technology. Will not get investment until the numbers work out relative to other options.
2010 to 2020 Renewable Hydrogen Plan

Critical Success Factors
- Rising oil prices stimulate the search for alternatives
- Public support for protecting the environment
- Availability of primary renewable energy sources
- General Motors roll-out in Hawaii
- Toyota Roll-out in Hawaii
- Private industry recognizing business opportunities
- Politically willing and leadership
- Dedicated funding

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<td>WIND</td>
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<td>BIOMASS</td>
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<td>HYDRO</td>
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<th>TASK 2: DEVELOP HYDROGEN INFRASTRUCTURE</th>
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<td>H2 DISPENSING STATIONS</td>
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<td>H2 DELIVERY</td>
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<td>H2 STORAGE</td>
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<tr>
<td>GM-LFET</td>
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<td>NAOI BUSES</td>
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<td>HELEON BUSES</td>
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<th>TASK 4: POLICY DEVELOPMENT</th>
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<td>H2 VEHICLE FUNDING PROGRAM LICENTES</td>
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<th>TASK 5: FUNDING</th>
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<td>REPLENISH HYDROGEN FUND</td>
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<th>TASK 6: COMMERCIALIZATION BY PRIVATE BUSINESS</th>
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<tr>
<td>RIX COMPANIES</td>
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<td>RENTAL CAR</td>
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Challenges
- Economic viability
- Large investment required to build H2 infrastructure
- Renewable energy sources need to be developed on a large scale
- Transportation applications need to be economically viable
- Legislative funding needs to be consistent
- Sense of urgency
- Barriers and inertia hard to overcome

START
2010
- HCEI
- 1 Oahu Gas Station
- Several supportive policies
- 4 Large-scale demo projects
  - HCATT
  - H2 Power Park
  - Renewable H2
  - GM FCV Rollout

TARGETS
2020
- Fleet of 5,000 FCVs
- 3 major car companies
- 10 Oahu gas stations
- 10 Hawaii gas stations
- 1 Geothermal hydrogen plant
- 2 Wind Hydrogen Plants
- 1 FCV Rental car company
- 50 H2 buses Oahu & BI
- Near-commercial H2 distribution
Major Tasks

Task 1: Develop Large-Scale Renewable Energy Sources:
  ➢ Geothermal, solar, wind, hydro and biomass.

Task #2: Develop Hydrogen Infrastructure
  ➢ Hydrogen Production, storage, delivery, dispensing stations

Task #3: Support Application & Demonstration Projects

Task #4: Policy Development

Task #5: Funding

Task #6: Commercialization by Private Business
Implementation Organization

- Implementation Authority – State Energy Office
- Senior Review Committee
- Implementation Advisory Panel
- Topic Teams
Fuel Cell Transportation Technologies

- Full-Size Transit Buses
- Para-Transit Buses
- Class8 Drayage Trucks
- Light Duty FCEVs
- Baggage Tow Tractors
- Medium Duty Delivery
- Heavy Duty Refuse Trucks
- APU Truck Refrigeration
- Mobile Generators
Potential Oahu Locations

1: Ft. Armstrong
2: Airport
3: Kaneohe Bay
4: Diamond Head Guard
5: Sandy Beach WWTP
6: HPower Trash Plant

5-miles radius
Potential Big Island Locations

- Volcano National Park (7)
- Hilo Airport (8)
- Kona Airport/NELHA (9)
- Kau Coffee Mill Hydro (10)
- Parker Ranch (11)
- Army Training Area (12)
- Hamakua Coast (13)
- Hawe Wind (14)
- UH Hilo (15)
- PGV Production (16)

Note: no dispensing @ PGV
5 tube trailers would be used to distribute H₂ to dispensing sites.
Potential Hydrogen Legislation

- Hydrogen Implementation Authority
- Hydrogen Investment Capital Special Fund
- City & County Honolulu Hydrogen Station
- County of Hawaii MTA Hydrogen Station
- Hydrogen Purity Test Station
- First Responder Equipment
  - Burn Props
  - Thermal Imaging Cameras
- Electric vehicles definition to include FCEV
- FCEV reporting & procurement requirements
Specific Goals

✓ Status of hydrogen in Hawaii
✓ Fueling needs and installation timeframe
✓ Shortfalls and Remedies
  ➢ Role of Government, OEMs
✓ Hydrogen/Electricity suppliers
✓ Energy security & assurance
✓ Economic development opportunities
AGENDA

- Introduction/EvStructure Background
- Education and Planning are Key
- The Barriers & Costing Examples
- AOAO/ HOA case study, Solutions, Summary
The Ev Structure Company is a local expert with nation-wide experience in the electric vehicle industry. We are a proud member of Honolulu Clean Cities and work as a strategic partner with various State and Non-profit entities working to expand the industry in Hawaii. Since 1998 after have installing the 1st charging station in Pasadena, CA for the Rav 1 program we have become an independent authority on Electric Vehicle Service Equipment (EVSE) and Charging Station Electrical Infrastructure.

Our partners and clients include: Action Properties, Hawaiiana, Enterprise Rental Car, Kohl's Retail Chain, BMW, SPX –GM, Chevy VOLT, the OpConnect Network, Green Lots, Car Charging Group (formerly Blink Network), ABM, NRG Deployment Partners. We are the go-to resource for Cities, Municipalities and Universities nationally. We provide EV readiness programs with a "cradle to grave" plan.

Our Specialty Services include: Objective expert advice and sourcing to the HOA, AOAO, Multi Unit Dwelling Communities, info on EV Charging Station options, acquisition, business models, policy, financial impact, tax and grant incentives and installation requirements for standard grid, smart grid and/or PV solar implementation with Solar Car Port Structures.

Our team works with: Commercial and residential property management staff, HOA/ AOAO homeowner's board, attorneys, real estate companies, and municipalities. We provide a full analysis of EV Charging Station Infrastructure, and can create a detailed EV readiness plan including site plans, energy auditing load calculations, equipment leasing & acquisition, cost analysis, EVSE MNF selection, engineering, ongoing KWH monitoring billing services and equipment service support.
EVSE is a Need. A New Curb Appeal & Amenity That Requires Good Planning

EVSE Units may require RF repeaters for underground wireless data communication
Experience with 730+ buildings nationwide... most buildings can only accommodate 6 Level II EVSE chargers

Example of Challenges to Electric Vehicle Charging in AOAO Multifamily & Mixed Residential Buildings

Case Study: An AOAO In Honolulu Hawaii USA.

Mixed Building:
• 250 Condo Units, 2 Retail stores
• 1 Tesla S BEV owner No place to Charge
• Year built: 2000

Parking:
• 500 spaces (mixed 1 and 2 tandem spaces per unit)
• 5 guest spaces (a negative per unit)
• 2 levels subterranean; 2 levels above-ground
• No street parking

Electrical:
• All original electrical work (2000)
• Constrained by transformer size
• AOAO fees pay for common area electricity
• Individually metered units located on each floor

Electrical Engineering Phase 1 Prescription
1) Transformer Load Measured for one week for peek Capacities 2) Retro fitted common area with new LED Lighting, Recommended PV Result

Freed up 60 amps, Now Capacity for (10) Level II and or (15) 110 outlets, Common Area Charger and opportunity for Solar Carport for top deck Phase 2 - Estimate to Install of 1 duel common are EVSE $23,459.00
AOAO Case Study

JOB NAME: One Ala Moana
Honolulu, HI

Developer: Howard Hugh's Corp., Kobayashi Group, The MacNaughton Group
Project Management Co.: P3 Management
Sales and Commissioning Company: EvStructure/retrofithawaii
Start Date: 3/10/13
Date of Completion: approx. 11/1/14
Permit: Closed TBD

Result: Tremendous Project Savings, Happy New Homeowners with this Amenity

Cost Break Down saved:
1. Engineer drawing for site layout, single line and installation for plan check, meet with city to submit and obtain approval $1,500.00
2. Coring, Installation Labor and Material (Includes 100kVa Transformer) $12,000.00
3. (3) x Opconnect Mark II Duel EVSE w/Cord Management $21,990.00
4. Paint parking stall for EV and install wheel stops $1,200.00
5. 1 EvGauge KWH Data Management 3,700 plus 15.00 a mo. mgmt Per driver

Project Total: $23,190.00

Total Saved speckled into initial planning $24,000 +
Summary

- Electric Vehicles are here and in demand
- EDUCATION is A MUST: HOA/AOAO/MUDs, Attorneys, Reserve companies, Architects, Electricians, Commercial and Residential Property Managers, EV Drivers, Senators and Representatives, etc. need to be informed and prepared.
- People don’t plan to fail, they fail to plan; EVSE MNF operating agreements must be customized to conform to the properties
- Properties need to prepare for EVSE Electrical Infrastructures and installations for enough 110v dedicated circuit outlets and or sufficient transformers sizing for Common area EVSEs. (Reserve Studies)
  - Implementing new standards in building codes for new buildings is an opportunity to increase infrastructure options in commercial and residential buildings
- Innovative solutions: Battery storage; Freewire
Introducing the Mobi, an integrated EV charging and energy management system.

The technology is a mobile Level 2 and Level 3 Fast Charger that uses second-life EV batteries as onboard energy storage.

FreeWire is the first and only commercial application of second-life EV batteries.
The Problem

Companies and utilities are struggling to keep up with the demands of EV charging.

Electric vehicle adoption is rising dramatically, and the current model of “dumb” stationary chargers imposes serious challenges.

- **Low Utilization**: Low vehicle turnover as employees refuse to rotate out of spots. (Avg = 2 cars / day / spot)
- **Difficult Installation**: Requires boring concrete across a parking lot to run conduit. (Plus permits & licenses)
- **Low Scalability**: Complex and lengthy process to scale up charging capacity. (CapEx & 6 months install)
- **High Infrastructure Cost**: Installation cost, infrastructure upgrades, and permitting – over $200k to set up 10 stations.
- **Productivity Loss**: Employee productivity is drained due to swapping cars & spots during the workday.
The Solution: Mobi Charger

The first solution that integrates EV charging with grid-level and building-level energy management.
Introducing the biggest innovation in **EV charging**, **energy storage**, and **energy management**.

---

1. **Technology:** The **Mobi Charger**
2. **Business Model:** **Charging as a Service**
3. **Energy Platform:** **Smart Energy Platform**

---

**EV Charging**
- Dual Level 2 + Level 3 Fast Charging.

**Energy Storage**
- 48kWh of lithium-ion batteries onboard.

**Energy Management**
- Automated demand response and building management.
Technology: The Mobi Charger

Business Model: Charging as a Service

Energy Platform: Smart Energy Platform

Grid Operators & Utilities
Property Owners
Facilities Managers

Active Energy Management

Note: Actual Screenshots
## Economics

### Cost per EV per Month
(includes energy costs)

<table>
<thead>
<tr>
<th></th>
<th>Level 2</th>
<th>Level 3</th>
</tr>
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<tbody>
<tr>
<td>Fixed Charging Station</td>
<td>$311</td>
<td>$1,087</td>
</tr>
<tr>
<td>FreeWire Mobi</td>
<td>$347</td>
<td>$514</td>
</tr>
</tbody>
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### Total Cost of Ownership (per EV) – Level 3

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<tr>
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<th>3 Years</th>
<th>5 Years</th>
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<tbody>
<tr>
<td>Fixed Charging Station</td>
<td>$60,838</td>
<td></td>
</tr>
<tr>
<td>FreeWire Mobi</td>
<td>$18,504</td>
<td>$30,840</td>
</tr>
</tbody>
</table>
Hawaii

State-specific barriers to increased EV infrastructure:

1. EVs are not concentrated in specific locations.

2. Lack of state-level funding and incentives to deploy charging infrastructure.

3. Multi-unit dwellings: no one’s figured it out.

Solution? Create artificial demand until you reach a tipping point.
Thank You
Alex Keros
Manager, Advanced Vehicle & Infrastructure Policy
Home vs. Work vs. Public Charging

• Overall EV drivers:
  Study Period 1/1/2012 – 12/31/2013
  o 84% of all charging events are at home
  o 16% not at home

• When workplace charging is available to an EV driver:
  (96 Volts with access to workplace charging Jan ‘13 – Dec ‘13)
  o 57% of charging events are at home
  o 39% at work
  o 4% at other locations (e.g. public)

  (707 Leafs with access to workplace charging Jan ’12 – Dec ’13)
  o 65% of charging events are at home
  o 32% at work
  o 3% at other locations (e.g. public)

Residential and workplace charging provide the vast majority of all charging.

Source: John Smart, INL, EV Project; Link to all reports = http://avt.inel.gov/librarybydate.shtml
Case Study: Major CA Workplace Customer

- **Infrastructure investment stimulates EV adoption!**

If you build it they will come...

and ports will still be used everyday

![Chart](image-url)
Maryland 8
Connecticut 2
Kentucky 12
Georgia 2
New York 51
Ohio 30
Michigan 278
Indiana 8
Illinois 2
Arizona 2
Kansas 2
Texas 3
California 32
Connecticut 2
Maryland 8
Georgia 2

432 GM WORKPLACE CHARGING STATIONS
Including 21 Assembly Plants
(23% Solar; 2 ADA friendly; 400 add’l private; 63% 240V and 37% 120V)

Also: Chevrolet and Cadillac dealers have installed approximately 5,900 charge stations at their locations for owner use – 17 of these dealerships use solar charging canopies.
DOE’s Workplace Charging Challenge Partners

Goal is tenfold increase in 5 years!
A California Road Map: The Commercialization of Hydrogen Fuel Cell Vehicles

The realization of fuel cell electric vehicles and supporting infrastructure requires a road map for investments in fuel cell electric vehicles and hydrogen fueling stations.

June, 2012

Streamlining the Permitting and Inspection Process for Plug-In Electric Vehicle Home Charger Installations

Report and Recommendations, Version 2
July 2012

Zero-Emission Vehicles in California: COMMUNITY READINESS GUIDEBOOK

Toward 1.5 Million Zero-Emission Vehicles on California Roadways by 2025

Published Fall 2013, First Edition.

This Guidebook is intended to be an accessible informational resource that supports the expansion of zero-emission vehicles. It may be reproduced and distributed without permission. Please acknowledge this Guidebook as a source of information when using its content in other documents or presentations.
General Motors | EPRI/Utility Collaboration

• Largest existing auto-utility collaborative effort -- formed in 2007
• Over 50 utility members and the Electric Power Research Institute (EPRI)
• Focus areas: Vehicle-to-Grid Technology, Aligned Messaging and Policy Priorities, New Business Opportunities (EV-to-Grid)
A growing PEV market benefits everyone

- Individual benefits: fuel savings, quiet and exciting ride & handling
- Society benefits: energy security, environment (local air, climate), and grid reliability
- Utility benefits: a smart load that drives new revenue to keep rates low

Utilities need to be active participants in growing the PEV market

- This is a “learning” transition and requires hands-on experience to shape next steps
- The PEV market will not escape “niche” unless utilities (and regulators) get involved

Active role in home (including MUDs) and workplace charging

- PEVs are already very smart and will do most charging at home – as the PEV market grows, utilities will want to ensure good load balancing across the service territory (off-peak EV rates, smart charging)
- Workplace charging is key to growing PEV awareness and corporate relationships are key to utilities - a utility will want to ensure healthy corporate engagement

Active role in PEV outreach and education

- Utilities are trusted 3rd parties and operate at a local level – key for building awareness

Longer term – pilot projects

- Utilities need to explore the role of PEVs in ancillary services, V2H, V2G, and battery secondary use to address growing issues in renewables, intermittency, storage, outage
What Infrastructure strategies are most important during the market launch of PEVs?

Simplicity & Flexibility.

Necessary Outcome:

Customers looking for easy solutions.
Investing in a More Sustainable Hawaiʻi

HCEI 2.0

January 14, 2015

ulupono

INITIATIVE
Who is the Ulupono Initiative?

• Founded in 2009, we are a Hawai‘i-focused impact investment firm that uses for-profit and non-profit investments to help catalyze large-scale, replicable change toward a more self-sufficient Hawai‘i by focusing on:

More Locally Produced Food

More Renewable Energy

Waste Reduction

Our Founders:
Pam & Pierre Omidyar
Our Goal: Increase Locally Grown Food

- By 2030, we want 30% of our food grown locally.
Our Goal: Locally Produced Clean, Renewable Energy

• By 2030, we want 60% locally produced clean, renewable energy.
Our Goal: Reduce, Recycle and Reuse Waste

• By 2030, we want 85% total waste recycled, reused or raw material input.
Projects We Support

• Hawai‘i Dairy Farms
• Hawai‘i School Garden Network
• Honolulu Seawater Air Conditioning, LLC.
• Paniolo Cattle Company
• MAʻO Organic Farms
• Re-use Hawai‘i
• SolarCity
Transportation Efforts

Biofuels

EV Infrastructure

VMT Reduction

Way Sine

Bikeshare Hawai‘i

Policy Support (Carshare)
Hawai'i – Earth's most isolated land mass has reason to be more self-sufficient. 91% reliant on food imports and 92% reliant on imported energy. Limited space for waste disposal.