Why add hydrogen to Oregon’s zero carbon transport strategy?

Presentation for the Oregon Global Warming Commission
Matthew Klippenstein, P.Eng.
2019 October 25
Presentation at a glance

1. About me
2. Batteries are like exoskeletons
3. Oregon’s transportation emissions
4. $$$$$$$
5. Consumer goods $≠$ Commodity goods
6. Wrap-up
1A. About Me

B.C.-based chemical engineer

- Fuel Cells - 15 years
  2 years co-authoring the *Fuel Cell Industry Review*
- Renewable Energy - 2 years
- EV Infrastructure - 1.5 years (condos / workplaces)

- first car-sharing membership - 1999
- PHEV owner - 2012 (1\(^{st}\) home charge 2016)

- current consulting client: fuel cell sector
- next client: EV infrastructure sector
1B. About Me (2)

Canadian EV market tracking since 2013

Assisted with / co-authored white papers on district energy, wind, EV infrastructure, hydrogen and fuel cells.

Of most relevance to OGWC:


2A. Batteries are like exoskeletons

exoskeletons  endoskeletons  batteries  fuel cells

Source article can be found here.
2B. Gov’t interest in vertebrates

¥ (2010-2020)  ¥ (expected 2021-)

batteries  fuel cells
2C. Private interest in vertebrates
3A. OR’s 2017 transportation emissions

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>CO₂ Emissions (MT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>14.6</td>
</tr>
<tr>
<td>“Diesel+”</td>
<td>8.8</td>
</tr>
</tbody>
</table>

(diesel, jet fuel, kerosene, fuel oil)

3B. OR’s 2017 transportation emissions

**Gasoline**
- 14.6 MT CO$_2$

**“Diesel+”**
- 8.8 MT CO$_2$
  (diesel, jet fuel, kerosene, fuel oil)

<table>
<thead>
<tr>
<th>Batteries</th>
<th>Fuel Cells</th>
</tr>
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<tbody>
<tr>
<td><img src="image1.png" alt="Batteries" /></td>
<td><img src="image2.png" alt="Fuel Cells" /></td>
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</tbody>
</table>
3C. OR’s 2017 transportation emissions

Gasoline

**14.6 MT CO₂**

“Diesel+”

**8.8 MT CO₂**

Annual Production (MW) for Wind and Solar

MW of nameplate production for:
- wind turbines in 1995
- solar photovoltaics in 2003

Wind (from 1992)
Solar (from 1996)

Fuel cell production is scaling \textit{exactly} along the trends of wind and solar in prior decades.

FCs in 2018 were where solar was in 2003, and wind in 1995.

Trend will hold through mid-2020s (end of chart) or longer.

10 MM FC vehicles by 2030 a stretch (2032?)
battery-style cost drops

Sources. Lithium-ion battery prices: Bloomberg NEF. Electrolyzer and PEM fuel cells: Liebreich Associates.
### H2Station® | Technology and product evolution

<table>
<thead>
<tr>
<th>Year</th>
<th>Product</th>
<th>Vehicles</th>
<th>Markets</th>
<th>Technology</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td><img src="image" alt="Product 2011" /></td>
<td><img src="image" alt="Vehicles 2011" /></td>
<td><img src="image" alt="Markets 2011" /></td>
<td><img src="image" alt="Technology 2011" /></td>
<td><strong>100kg/12 hours</strong> €1 million</td>
</tr>
<tr>
<td>2015</td>
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<td><img src="image" alt="Technology 2018" /></td>
<td><strong>500kg/12 hours</strong> €1 million</td>
</tr>
<tr>
<td>2020</td>
<td><img src="image" alt="Product 2020" /></td>
<td><img src="image" alt="Vehicles 2020" /></td>
<td><img src="image" alt="Markets 2020" /></td>
<td><img src="image" alt="Technology 2020" /></td>
<td><strong>1000kg/12 hours</strong> €1 million</td>
</tr>
</tbody>
</table>

**Source:** Nel Hydrogen. 2019 October.
5A. Consumer Goods ≠ Commodity Goods

**Consumer**

"it me"

**Commodity**

"TCO or lowest-cost"
5B. Consumer Goods ≠ Commodity Goods

Consumers generally aren’t rational or well-informed, and yet ...

An inherent challenge in anticipating and studying latent demand for ZEVs, however, is that mainstream consumers are still largely unaware of and confused about ZEV technologies (Axsen et al., 2017; Caperello and Kurani, 2012; Krause et al., 2013), and thus have difficulty expressing informed perceptions. As such, any elicited responses and preferences may be unformed, biased, and/or unstable. This situation, common to most emerging or not yet commercialized products, is described as the great challenge of market research (Hauser et al., 2006).

However, much of the existing consumer survey literature on ZEVs, particularly those using stated choice experiments, rely on a rational actor approach that assumes a well-informed respondent with existing, stable, and expressible preferences. In contrast, we follow the Reflexive Participant approach to survey design, which starts with the assumption that most respondents lack understanding of, experience with, or stable preferences for ZEVs. This approach builds on early consumer research on BEVs conducted in California in the 1990s (Kurani et al., 1994, 1996; Turrentine and Kurani, 1998), as well as more recent applications to ZEV consumer research in Canada and the US (Axsen et al., 2015b; Axsen and Kurani, 2009, 2013c). The Reflexive Participant approach to survey design aims to reduce hypothetical bias and enhance the usefulness of results through elements that include: collecting extensive data regarding respondents’ background and awareness relating to ZEVs, helping respondents to learn about ZEVs and to reflect on how ZEVs may relate to their lifestyles, and using stated response techniques that help respondents to construct preferences for ZEVs.
Even at CAD $150/kWh 45% of Canadians (polled in 2017, post Tesla Model 3 unveil) wanted conventional cars (CV). They didn’t even want conventional hybrids (HEVs).

Fig. 6. Respondent vehicle designs in the higher and lower price scenarios (n = 2123). ZEV total refers to the summation of respondents who select a PHEV, BEV, or HFCV design. Note: Higher and lower price design exercises reflect current and anticipated future prices, respectively (see Table 1).

CV and HEV oriented car buyers even expressed more 2nd-choice preference for fuel cell vehicles over BEVs. (There were 15,000 BEVs and 10 HFCVs in Canada at the time.)

Table 3
Distribution of second choice drivetrains among respondents in the lower price scenario (n = 2123).

<table>
<thead>
<tr>
<th>First choice (% of total sample)</th>
<th>% Distribution of second choices (of respondents with a given first choice)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CV</td>
</tr>
<tr>
<td>CV (45%)</td>
<td>–</td>
</tr>
<tr>
<td>HEV (33%)</td>
<td>68%</td>
</tr>
<tr>
<td>PHEV (12%)</td>
<td>14%</td>
</tr>
<tr>
<td>BEV (5.4%)</td>
<td>9%</td>
</tr>
<tr>
<td>HFCV (3.6%)</td>
<td>22%</td>
</tr>
</tbody>
</table>
5E. Recommendation

I believe it would be more effective for Oregon to methodically create state-wide H2 infrastructure than to rely on 100% car buyer conversion to BEVs.

It is not prudent to assume “rational actor” consumers.

Heavy-duty vehicle fleets will be the principal H2 beneficiaries, and Oregonian drivers will gain another ZEV option.
NB - Efficiency is a distraction with Consumer Goods.
By 2030 “micro” folks will harass BEV owners for their congestion-causing inefficiency. (Public transit advocates already do...)

Travel miles per 100 kWh AC renewable electricity
Data sources: canonical diagram, EPA, Efficiency Vermont.

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Bicycle and car icons made by Monik from Flaticon.com
6. Summary

1. I live in both the electric and H₂ worlds
2. Batteries are like exoskeletons
3. Gas/diesel split → electricity/hydrogen split
4. Fuel cell costs are collapsing, and
5. Consumer goods ≠ Commodity goods, so…

H₂ and infrastructure should be part of OGWC’s clean transportation planning.

(Definitely keep moving ahead with charging infrastructure though!)