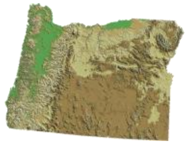
# Why add hydrogen to Oregon's zero carbon transport strategy?

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

*Map of Oregon: Wikipedia Commons*

# 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 (1st home charge 2016)

- current consulting client: fuel cell sector
- next client: EV infrastructure sector

# 1B. About Me (2)

EV market tracking since 2013

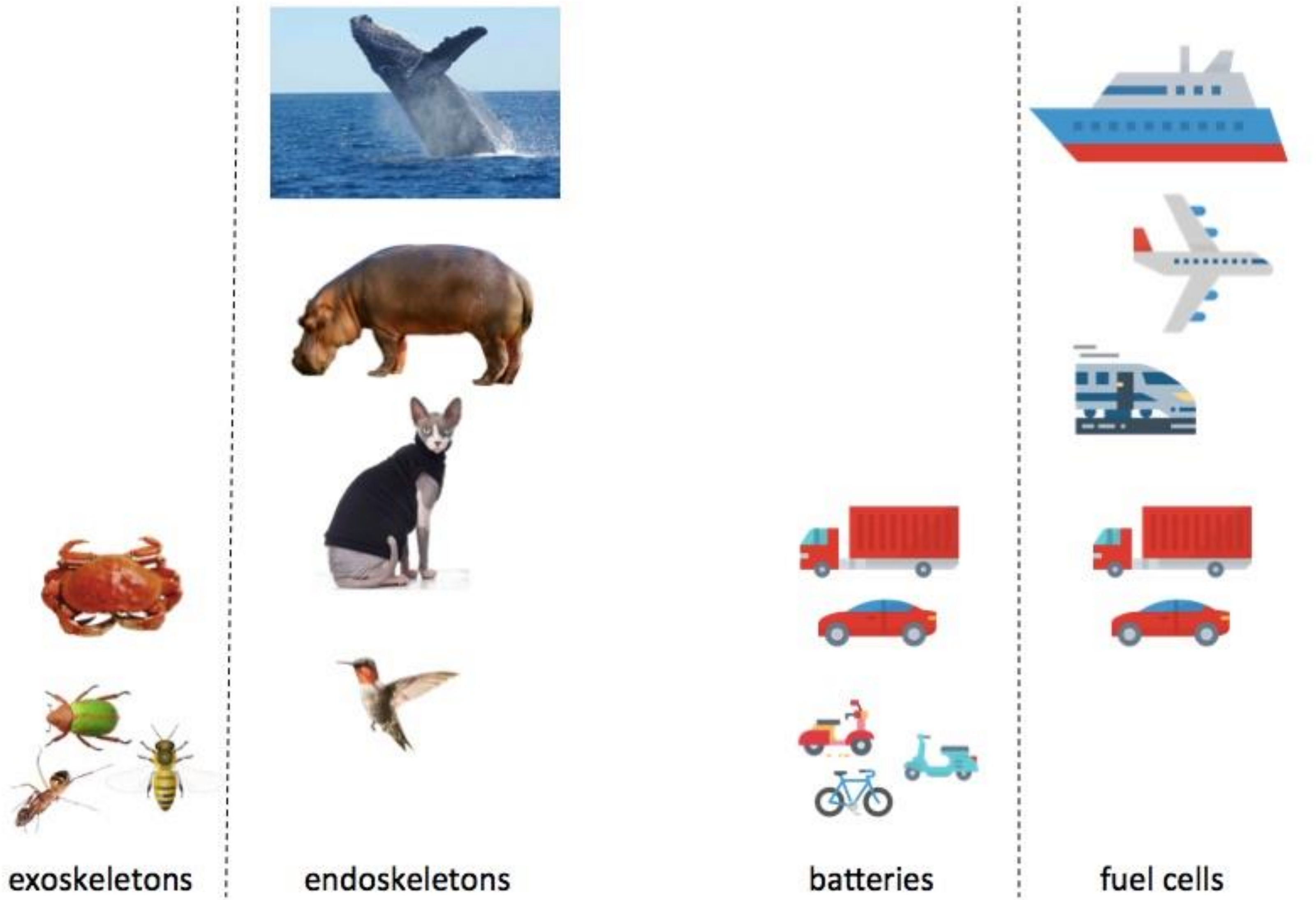
Assisted with / co-authored white papers on district energy, wind, EV infrastructure, hydrogen and fuel cells.

Of most relevance to OGWC:

City of Richmond and BC Hydro, *Residential Electric Vehicle Charging: A Guide for Local Governments* (via CM2P, Fraser Basin Council)

B.C. Ministry of Energy, Mines and Petroleum Resources, *British Columbia Hydrogen Study* (via Zen Energy Solutions)

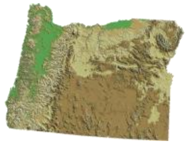
# 2A. Batteries are like exoskeletons



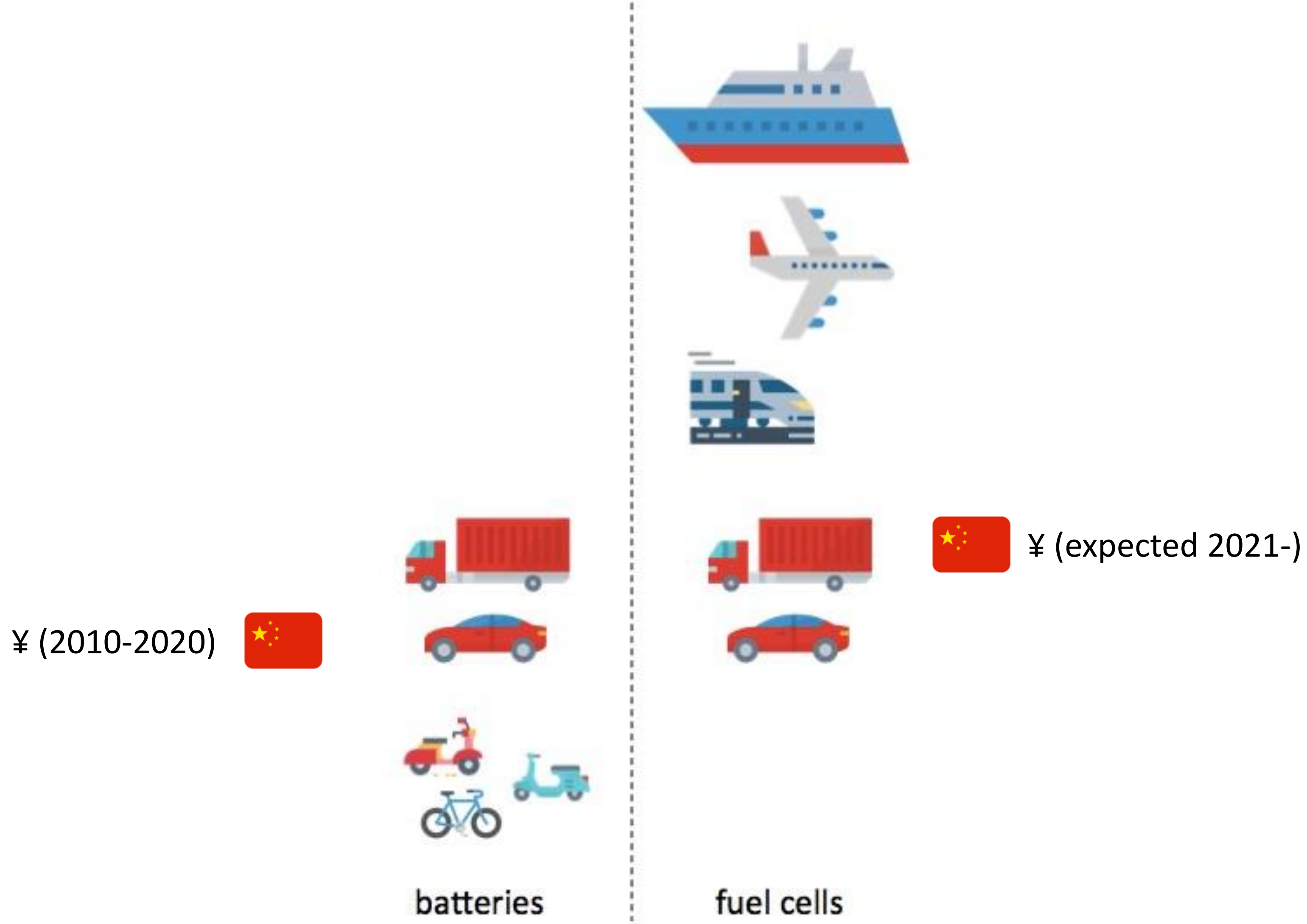


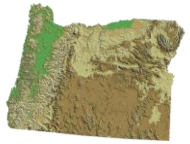

Animal images: Wikimedia Commons, Pixabay, PurePNG. Vehicle icons by Monkik and Smallikeart from Flaticon.com.

*Source article can be found here.*

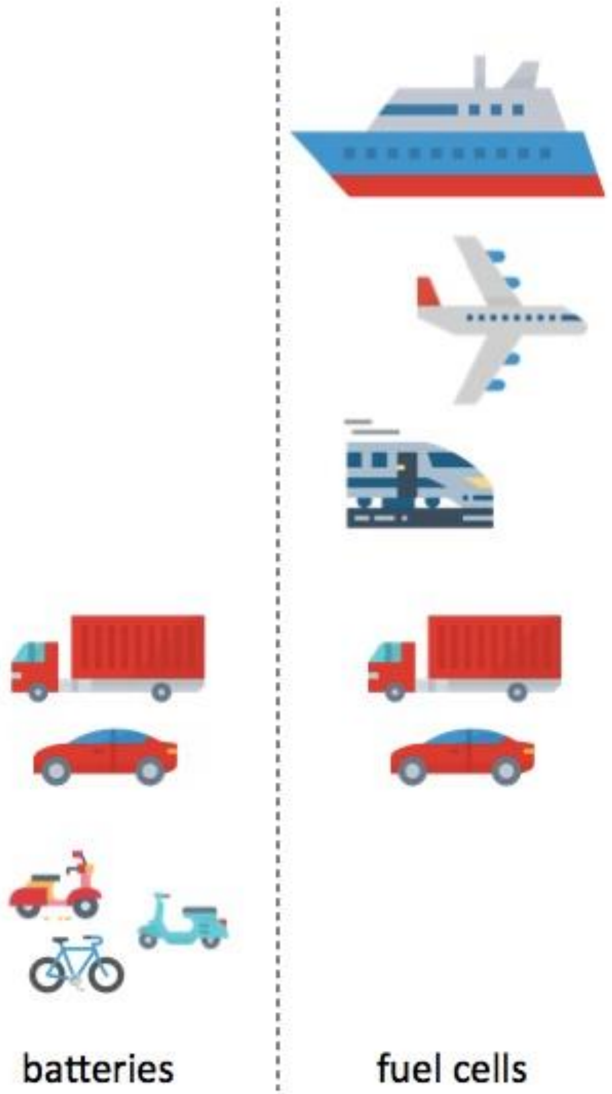


# 2B. Gov’t interest in vertebrates





# 2C. Private interest in vertebrates

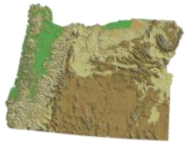



潍柴动力 WEICHAI POWER — 19.9% → BALLARD

Cummins — 100% → HYDROGENICS

Cummins — $$ → LOOP

BOSCH — 100% (auto) → POWERCELL



# 3A. OR's 2017 transportation emissions

## Gasoline

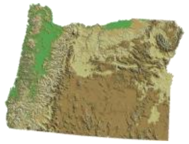
**14.6** MT $CO_2$

## " Diesel+ "

**8.8** MT $CO_2$

(diesel, jet fuel, kerosene, fuel oil)

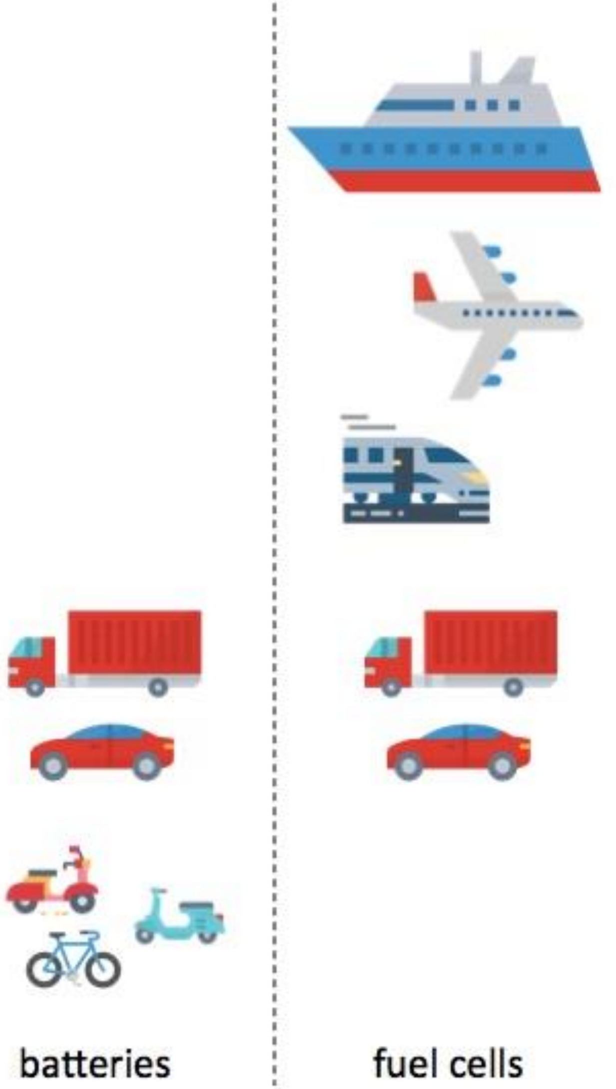
*Source: "Oregon Greenhouse Gas Sector-Based Inventory Data" –*
https://www.oregon.gov/deq/FilterDocs/ghg-sectordata.xlsx



# 3B. OR's 2017 transportation emissions

## Gasoline

**14.6** MT $CO_2$




## " Diesel+ "

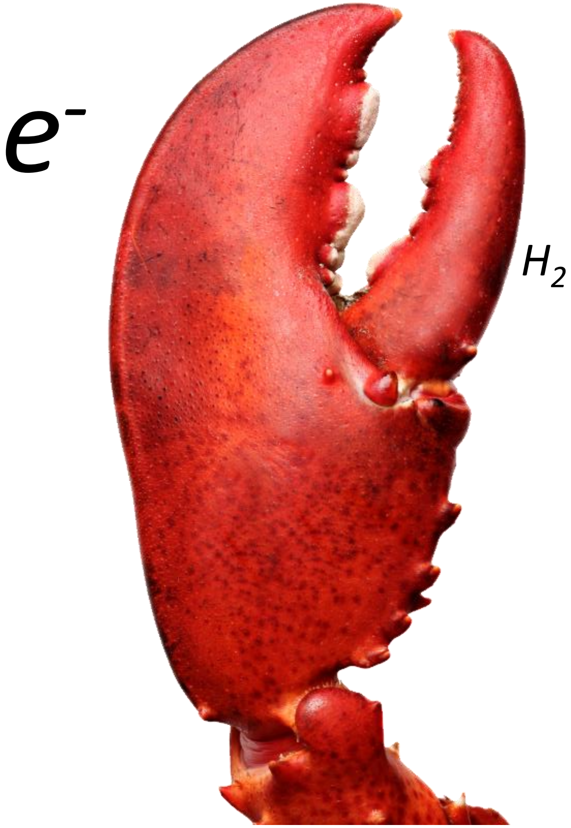
**8.8** MT $CO_2$

(diesel, jet fuel, kerosene, fuel oil)

# 3C. OR's 2017 transportation emissions

**Gasoline**

**14.6** MT $CO_2$




**" Diesel+ "**

**8.8** MT $CO_2$

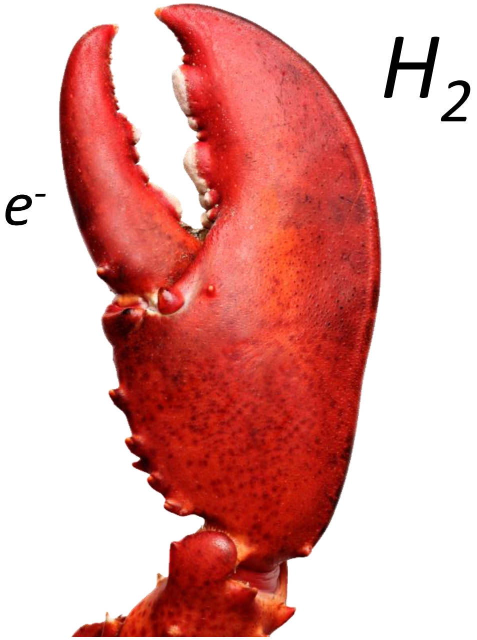
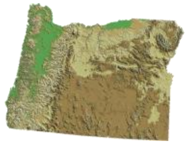
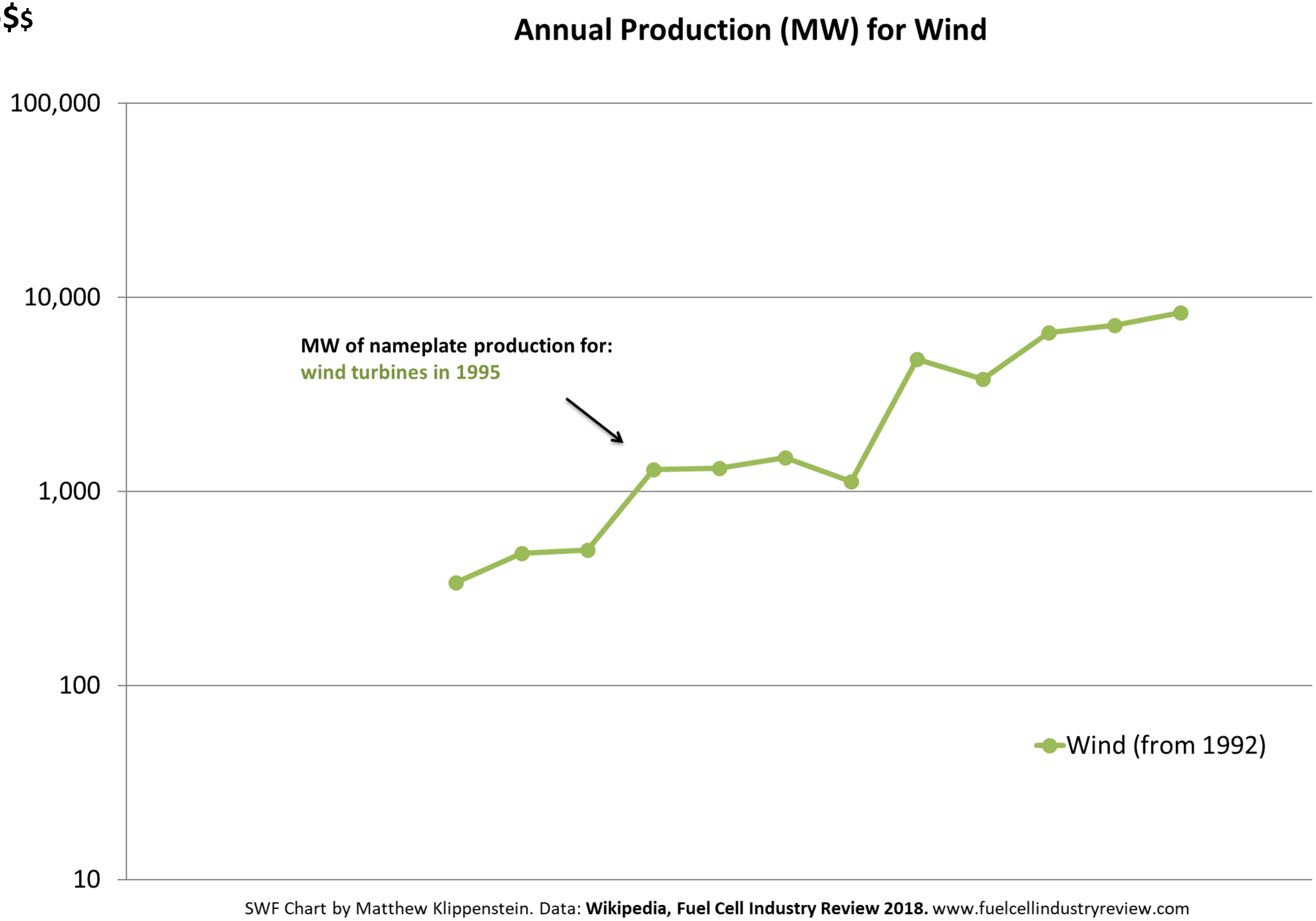
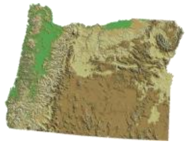



*Image: Pinterest. Pincer areas reflects approx. 14.6:8.8 ratio.*

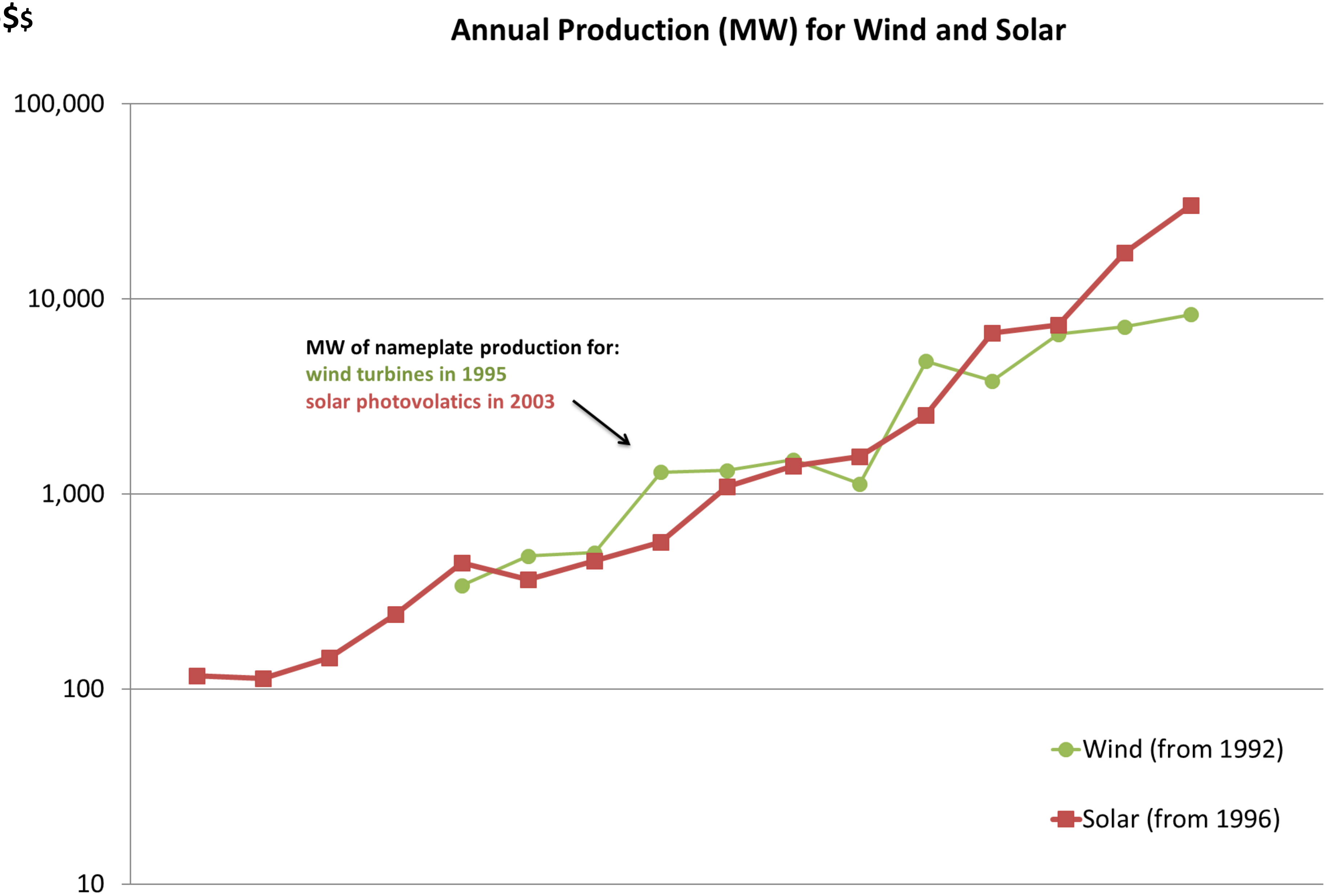


# 4A. $$$$$$


Annual Production (MW) for Wind
100,000
10,000
1,000
100
10
MW of nameplate production for:
wind turbines in 1995
Wind (from 1992)
SWF Chart by Matthew Klippenstein. Data: Wikipedia, Fuel Cell Industry Review 2018. www.fuelcellindustryreview.com



# 4B. $$$$$$




SWF Chart by Matthew Klippenstein. Data: **Wikipedia, Fuel Cell Industry Review 2018.** www.fuelcellindustryreview.com

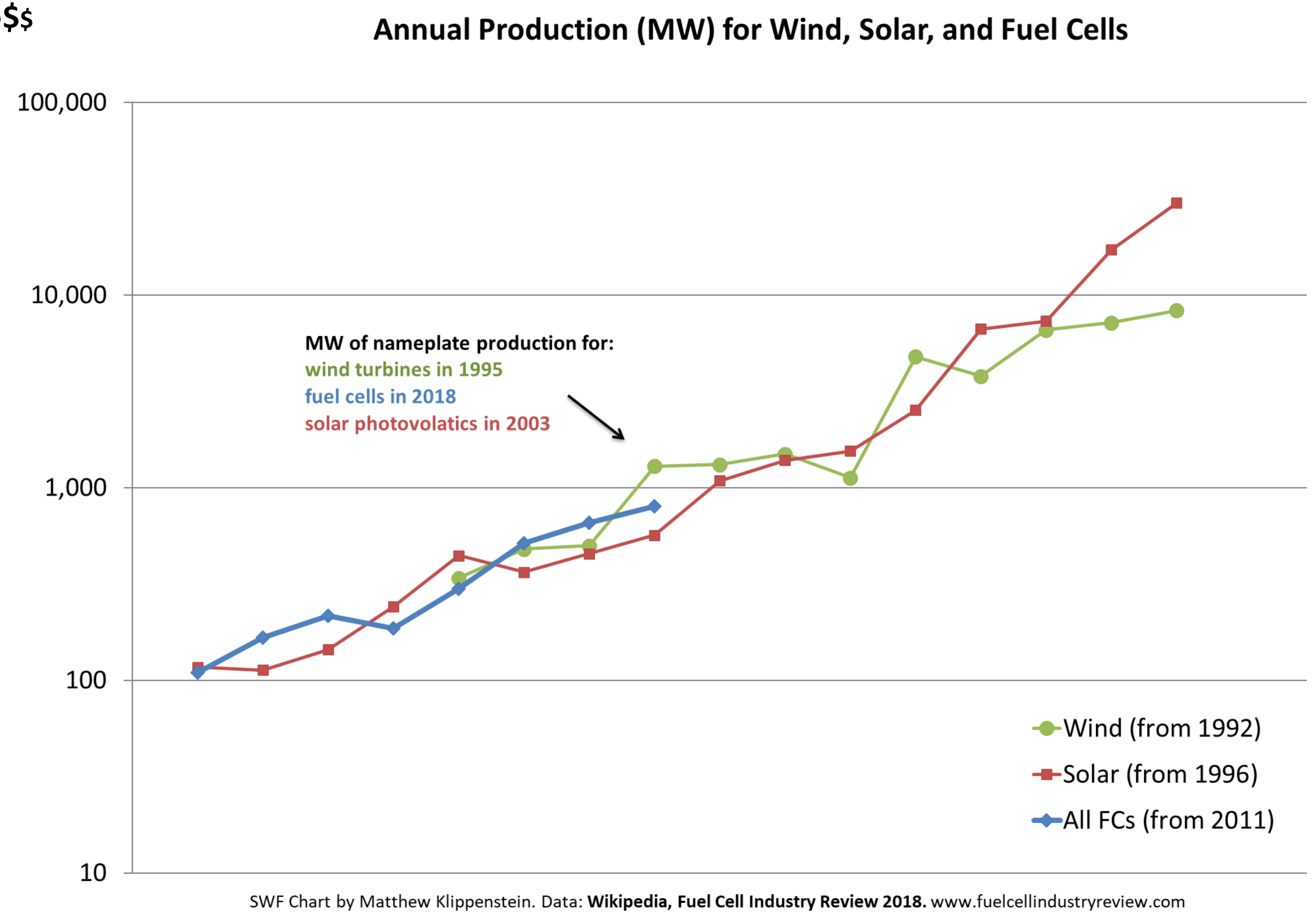
# 4C. $$$$$$

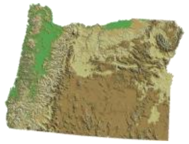
*Fuel cell production is scaling* ***exactly*** *along the trends of wind and solar in prior decades.*

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

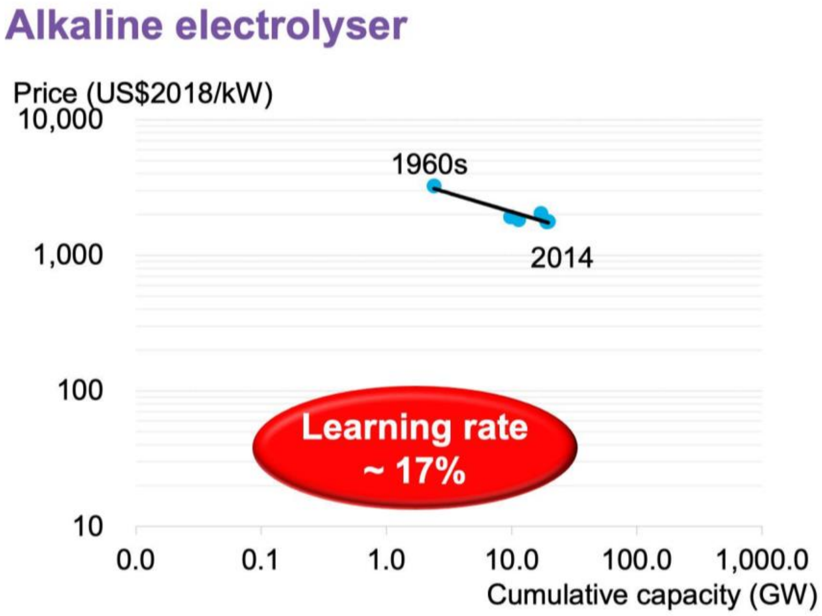
*Trend will hold through mid-2020s (end of chart) or longer.*

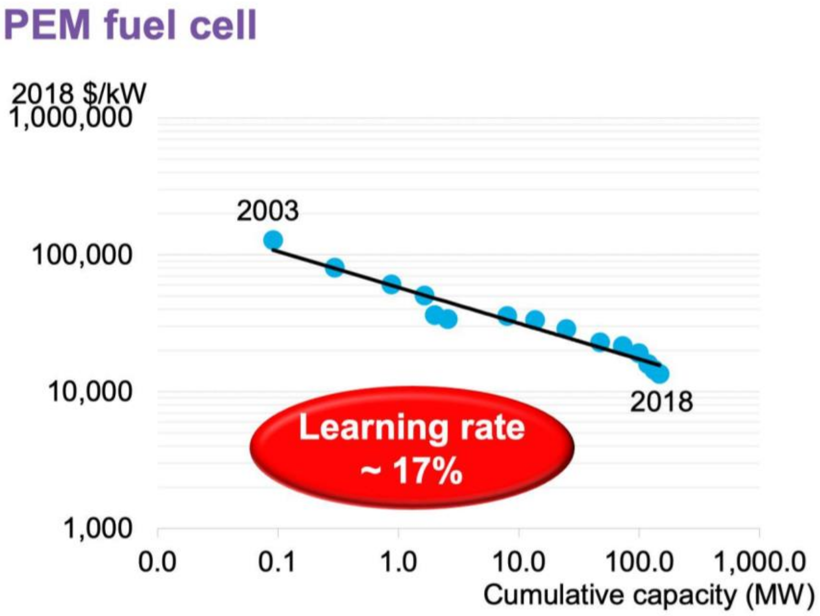
*10 MM FC vehicles by 2030 a stretch (2032?)*





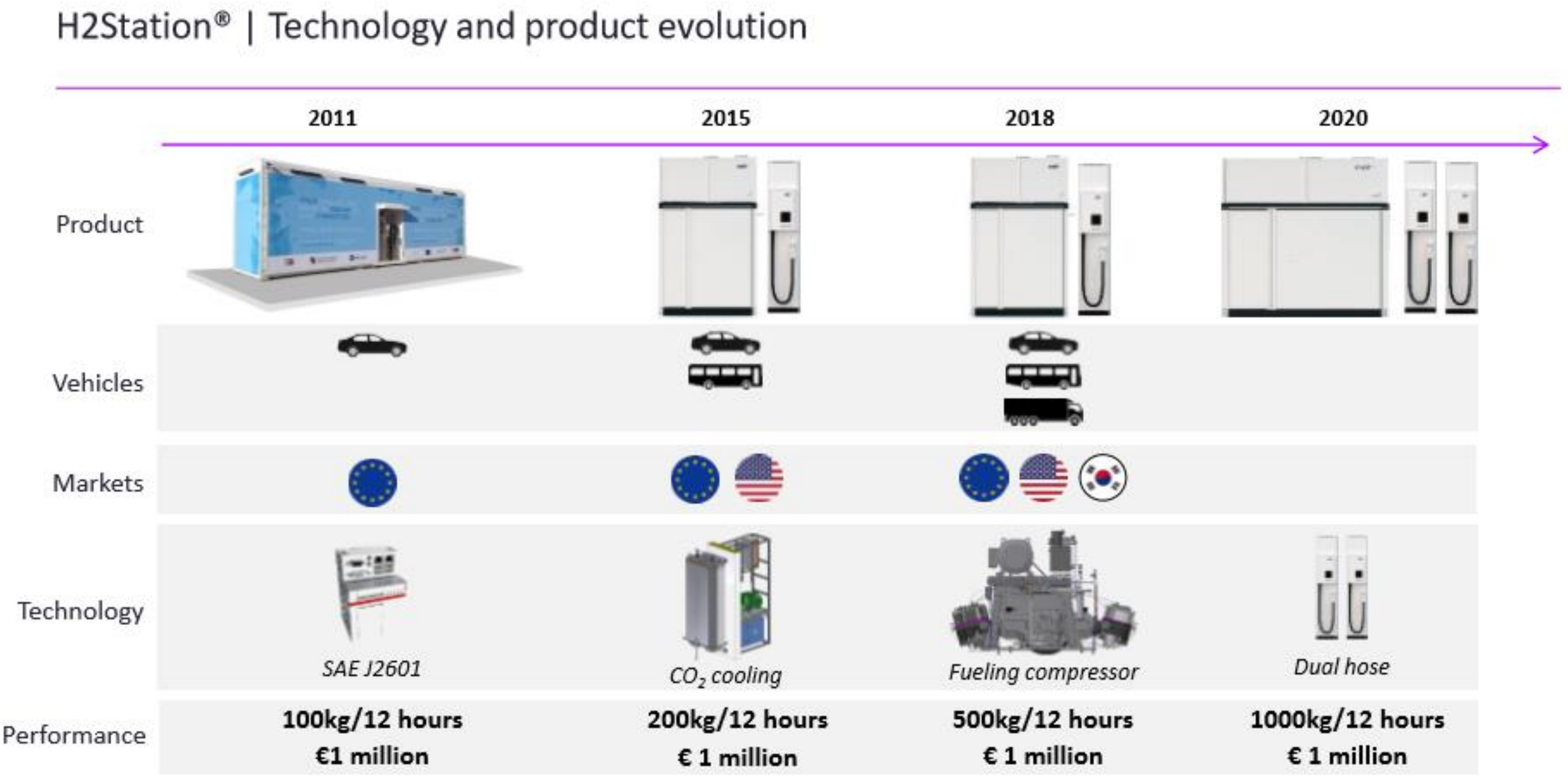
# 4C. $$$$$$ battery-style cost drops

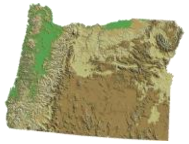

*Sources. lithium-ion battery prices: Bloomberg NEF. Electrolyzer and PEM fuel cells: Liebreich Associates.*

# 4D. $$$$$$ battery-style cost drops




*Source. Nel Hydrogen. 2019 October.*

Matthew Klippenstein P.Eng. @ElectronComm



# 5A. Consumer Goods ≠ Commodity Goods

## Consumer

"it me"

Chick-fil-A

REI co-op


## Commodity

"TCO or lowest-cost"

McDonald's

amazon

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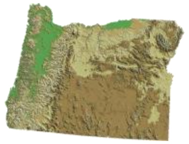

# 5B. Consumer Goods ≠ Commodity Goods

## 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.

Long, Z., Axsen, J., Kormos, C., Goldberg,S., *Latent demand for zero-emissions vehicles in Canada (Part 1): Insights from a design space exercise*, **Transportation Research Part D 67 (2019) 51-66**.

# 5C.

**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).**

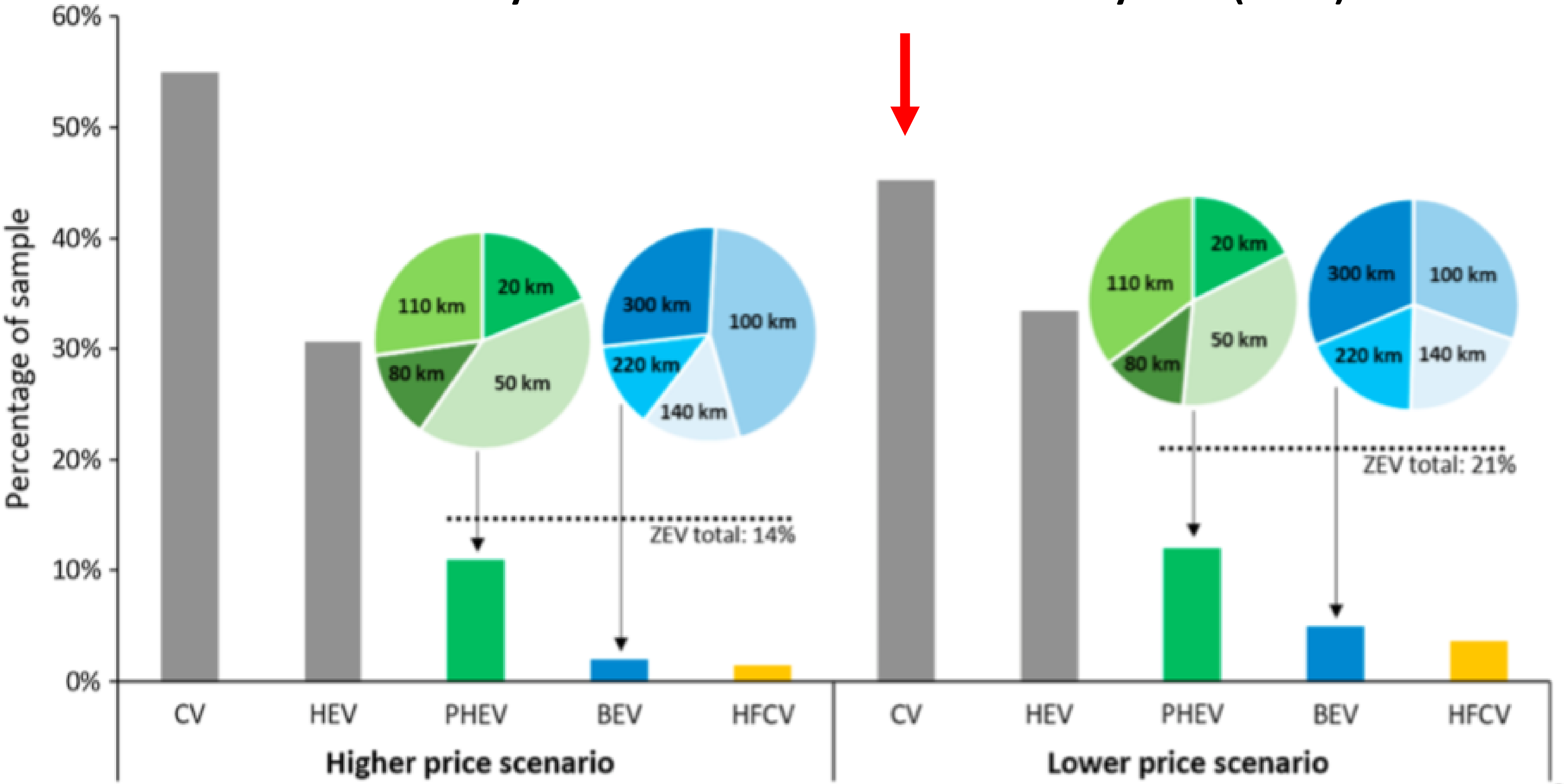


**Fig. 6.** Respondent vehicle designs in the higher and lower price scenarios (n = 2123). ZEV total refers to the summation of respondents who select a PHEV, BEV, or HFCV design. Note: Higher and lower price design exercises reflect current and anticipated future prices, respectively (see Table 1).

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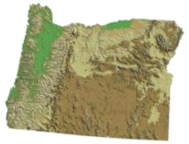


# 5D.

**CV and HEV oriented car buyers even expressed more 2nd-choice preference for fuel cell vehicles over BEVs.**

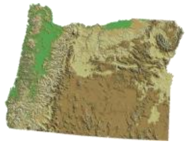
**(There were 15,000 BEVs and 10 HFCVs in Canada at the time.)**

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

| First choice (% of total sample) | % Distribution of second choices (of respondents with a given first choice) | | | | |
|---|---|---|---|---|---|
| | CV | HEV | PHEV | BEV | HFCV |
| CV (45%) | – | 86% | 6% | 2% | 6% |
| HEV (33%) | 68% | – | 21% | 5% | 6% |
| PHEV (12%) | 14% | 48% | – | 34% | 5% |
| BEV (5.4%) | 9% | 21% | 63% | – | 8% |
| HFCV (3.6%) | 22% | 46% | 13% | 18% | – |



Long, Z., Axsen, J., Kormos, C., Goldberg,S., *Latent demand for zero-emissions vehicles in Canada (Part 1): Insights from a design space exercise*, **Transportation Research Part D 67 (2019) 51-66**.



# 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.**

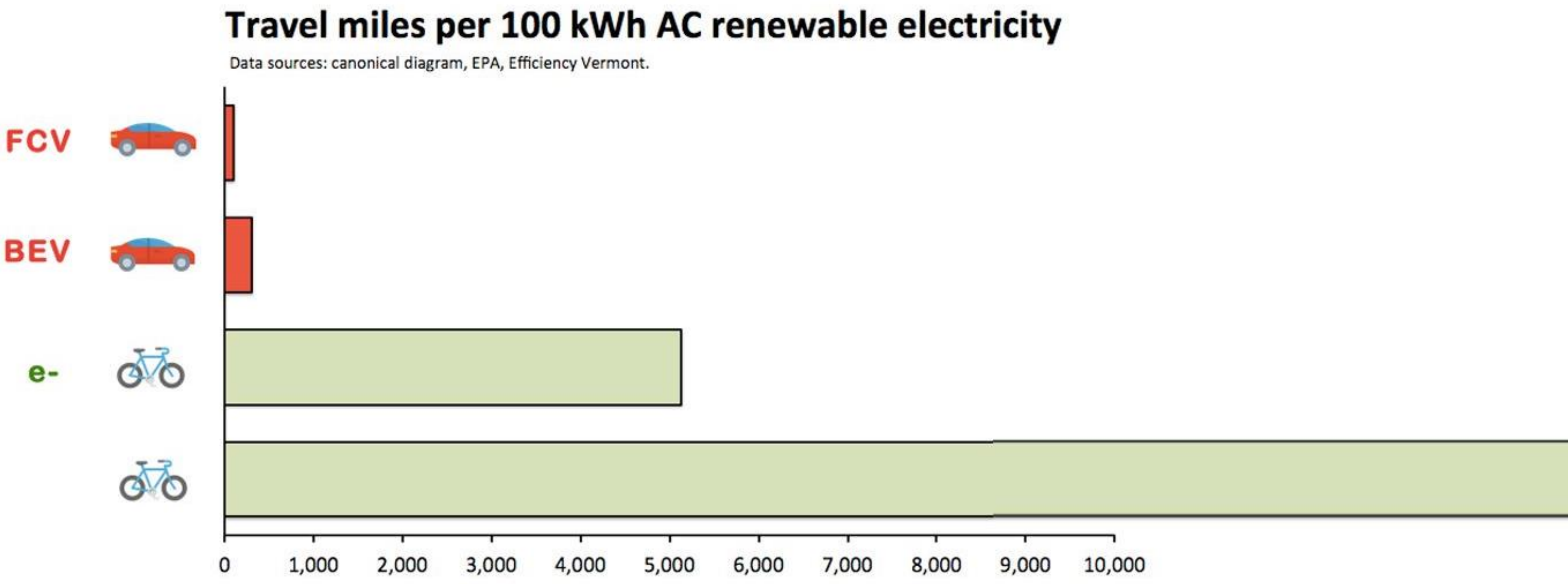
**It is not prudent to assume “rational actor” consumers.**

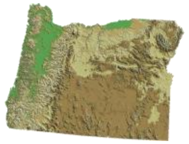
**Heavy-duty vehicle fleets will be the principal H2 beneficiaries, and Oregonian drivers will gain another ZEV option.**

Long, Z., Axsen, J., Kormos, C., Goldberg,S., *Latent demand for zero-emissions vehicles in Canada (Part 1): Insights from a design space exercise*, **Transportation Research Part D 67 (2019) 51-66**.

# 5F. 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…)**





# 6. Summary

1. I live in both the electric and $H_2$ 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…

$H_2$ and infrastructure should be part of OGWC’s clean transportation planning.

***(Definitely keep moving ahead with charging infrastructure though!)***