2023 February 2

Amy Sopinka
Acting Executive Director
Low Carbon Fuels Branch
B.C. Ministry of Energy, Mines, and Low Carbon Innovation
P.O. Box 9314 Stn Prov Govt
Victoria, B.C. V8W 9N1

Dear Ms. Sopinka:

RE: Hydrogen BC Feedback on the Low Carbon Fuels Act

> *Please find attached Hydrogen BC's feedback on the LCFS Technical Requirements Intentions Paper. We recognize that it is being submitted after the requested deadline of 7 a.m. January 30, 2023 and hope that in light of exceptional circumstances, our contributions may receive consideration.*
> *My mother's nursing home contacted us on Saturday (Jan 28) that her condition had worsened, and soon aftewards, that we should urgently gather our relatives. We visited her Sunday (Jan 29); she passed away that evening. I spent January 30 at the nursing home clearing her effects, making arrangements with the mortuary, processing legal documents and arranging to pick up an overseas relative who had flown in. In so doing I was too preoccupied to ask work colleagues to inquire and request a small extension. The pre-cremation final viewing was on February 1, followed by meals, reflections and reminscences with relatives.*
> *– Matthew Klippenstein, Executive Director, Hydrogen BC*

Hydrogen BC was formed in 2020 by the Canadian Hydrogen and Fuel Cell Association with the support of the Government of British Columbia, as a provincial affiliate of the natioanl association. We represent more than 30 world-leading B.C. organizations across the hydrogen value chain.

The B.C. Hydrogen Strategy[1] projects that clean hydrogen can contribute to 11% of the Province's emissions reductions from 2018 levels to a Net Zero 2050. Of those emissions reductions, the majority (60%) are projected to come from transportation.[2]

[1] *B.C. Hydrogen Strategy*, 2021. Available at: https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/electricity-alternative-energy/electricity/bc-hydro-review/bc_hydrogen_strategy_final.pdf
[2] *B.C. Hydrogen Strategy*, Page 19.

As such the Low Carbon Fuels Act (LFCA) is a policy apposite to hydrogen and our member organizations. British Columbia is home to more than half of Canada's world-renown hydrogen fuel cell cluster, and to technology leaders in hydrogen combustion as well.

The Act comes at an appropriate time, as global greenhouse gas (GHG) reduction targets have become much more ambitious since the Greenhouse Gas Reduction Act was first passed in 2007. In 2007 even leading governments only envisioned incremental climate policies, targeting modest long-term GHG reductions. As of 2023 many governments have embraced *transformative* climate policies, aiming for Net Zero.

Clean hydrogen was largely overlooked in the era of incremental policy, but is a keystone of Net Zero commitments. Hydrogen technologies including fuel cells and electrolyzers have also advanced steadily in the past 15 years. The fuel cell industry continues to scale up along the trajectory of the early wind energy and solar photovoltaics sectors, and early trends suggest hydrogen electrolyzers may scale up faster than all three.[3]

Hydrogen BC is pleased to work with other Associations, stakeholders and rightsholders to provide our responses to the *Technical Intentions* paper, including but not limited to calculations of Energy Effectiveness Ratios (EER). We believe the *Technical Intentions* paper's calculated EER for hydrogen fuel cells and hydrogen combustion underestimates the real-world EER that would be observed in British Columbia. Applying a similar lens to our cleaner-fuel allies in the natural gas and electricity space, we have made some recommendations in those categories as well.

Hydrogen BC encourages the B.C. Ministry of Energy, Mines and Low Carbon Innovation (EMLI) to consider our response, and are available for further discussion at your convenience. We thank EMLI and the Low Carbon Fuel Standard team for the opportunity to participate in this inquiry process.

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[3] Statistical dataset with fully-documented sources for each of wind, solar PV, fuel cells and electrolyzers) is available upon request. The parallels described in this December 2017 article in GreenTechMedia (now part of Wood McKenzie) continue to hold: https://www.greentechmedia.com/articles/read/fuel-cells-in-2017-are-where-solar-was-in-2002

Feedback from Hydrogen BC is subdivided by *Technical Intentions* paper section below.

3.1 Target Carbon Intensity

While disclaiming regulatory expertise, Hydrogen BC would request that the Ministry's policy with respect to Target Carbon Intensity in some manner consider the question of credit price stability, perhaps through guardrails or periodic adjustments to the target R values for gasoline and diesel. Like stock market prices, credit market prices must be allowed to fluctuate – but even stock markets have so-called "circuit breakers" to rein in volatility.

The reason for this request is the collapse in the California Low Carbon Fuel Standard Credit price, which has dropped by two-thirds (2/3) since January 2021, shown in Figure H1.

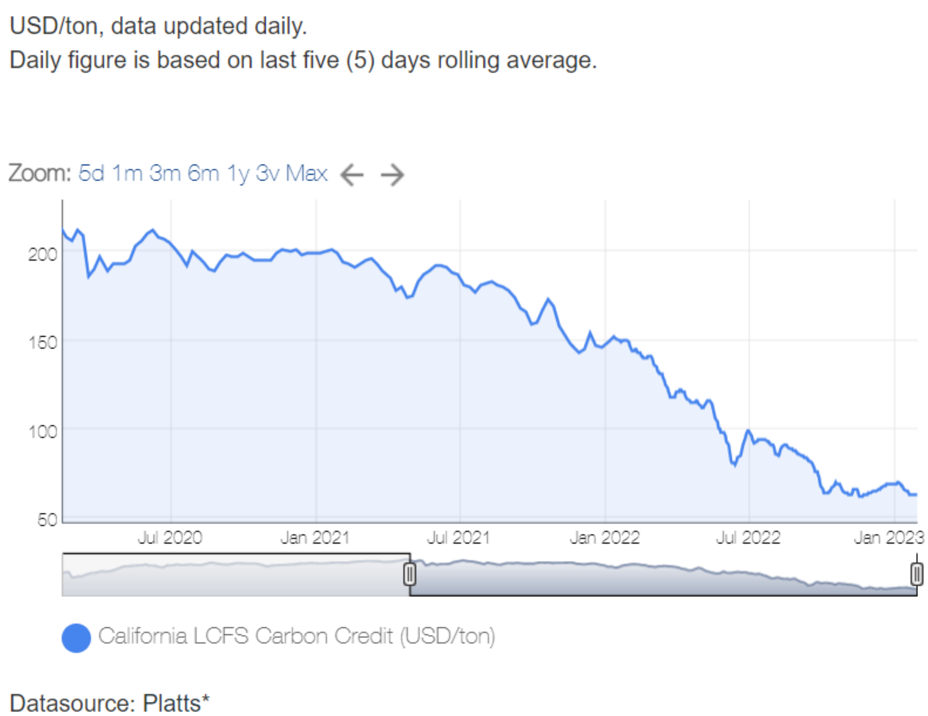

Figure H1. California Low Carbon Fuel Standard Credit Price. Source: Platts[4]

[4] California Low Carbon Fuel Standard Credit price according to Platts, Neste.com, accessed 2022 January 31, https://www.neste.com/investors/market-data/lcfs-credit-price#b2bb836a.

For comparison purposes an excerpt from the most recent B.C. LCFR Quarterly Credit Transit Activity report is included in Table H0 below.[5]

Table H0. Historical B.C. LCFR Credit Clearing Prices. Source: Government of B.C.

Time Period [1]	Transfers (number)	Total Volume (credits)	Average Price [2] ($ per credit)	Minimum Price ($ per credit)	Maximum Price ($ per credit)	A	B	C
Q4 2022	46	307,480	$443.93	$340.00	$480.00	39	2	5
Q3 2022	37	364,882	$447.97	$400.00	$490.00	36	1	0
Q2 2022	8	28,060	$402.59	$340.00	$485.00	N/A	N/A	N/A
Q1 2022	27	247,755	$467.32	$345.00	$497.77	N/A	N/A	N/A
CY 2021	85	551,906	$447.24	$85.00	$519.19	N/A	N/A	N/A
CY 2020	32	102,890	$250.44	$32.50	$385.20	N/A	N/A	N/A
CY 2019	35	263,512	$269.33	$32.93	$324.08	N/A	N/A	N/A
CY 2018	48	435,221	$193.44	$55.00	$210.50	N/A	N/A	N/A
CY 2017	31	240,164	$164.30	$60.00	$185.00	N/A	N/A	N/A
CY 2016	15	198,705	$170.93	$100.00	$190.00	N/A	N/A	N/A
CY 2015	2	14,354	$169.95	$20.00	$170.00	N/A	N/A	N/A

[1] Q: quarter; CY: compliance year.
[2] Excludes credit transfers reported with a zero or near-zero price.

Hydrogen BC believes it would be valuable for EMLI to learn from California regulators how their credit price collapse happened, even if this might slightly delay the Act's schedule. The California credit market has correlated with a dramatic spike in retail hydrogen prices, which will impair market adoption of clean hydrogen in transportation. To be clear correlation is not causation; perhaps regional natural gas or electricity (for hydrogen electrolysis) prices rose dramatically in recent years. We strongly believe it would add value to understand the causes of the California credit price collapse before the Low Carbon Fuels Act is implemented.

In the absence of mitigating measures – circuit breakers, to use the stock market analogy – the large fluctuations in California's credit prices could dissuade LCFR solutions providers from investing in projects in British Columbia.

[5] Low Carbon Fuel Credit Market Quarterly Report dated 2022 January 05, Government of British Columbia, accessed at: https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/electricity-alternative-energy/transportation/renewable-low-carbon-fuels/rlcf017_-_low_carbon_fuel_credit_market_quarterly_report_20230105.pdf

Unlike the stock market, B.C. LCFR credits serve a purpose; they help the Province decarbonize and achieve its CleanBC emissions reductions goals. For example a collapse in credit values could be used as a market signal that the Province can raise its R values more aggressively and *achieve its target Percent Reduction for diesel and gasoline ahead of 2030*.

For the reasons above we recommend that EMLI determine what ”circuit breakers” would be appropriate in the event of B.C. LCFR credit price instability, which could occur if large projects come online and suddenly increase the supply of available credits.

3.2 Energy Effectiveness Ratio (EER)

Hydrogen BC believes that higher EER’s for hydrogen based propulsion would be more reflective of real-world performance in British Columbia, than the figures offered in Tables 4 through 6. We imagine Electricity proponents will provide similar feedback for their technologies; CNG or LNG respondents may do so as well.

Could the Low Carbon Fuels Branch (LCFB) hold an informational hearing so proponents can present their data and directly answer questions from LCFB staff and other participants? Conversations can immediately clarify the sorts of misinterpretations and misunderstandings that purely-written communications are subject to, and a hearing would approximate a peer review process, thereby partially insulating the LCFB from future criticism by unhappy proponents.

Hydrogen Internal Combustion

In Table 4’s calculation of diesel EER’s, hydrogen in an internal combustion engine is assigned a value of 0.9. This is the same value assigned to a natural gas spark ignited engine.

Data received from Hydrogen BC member Westport Fuel Systems would appear to show there are efficiency differences between Spark-Ignited and High Presssure Direct Injection (HPDI) combustion both for natural gas and for hydrogen.

In the *Technical Intentions* paper discussion on compressed natural gas (page 34) it is noted that observed natural gas EER ratios ranged from 0.82 to 1.0. If there was an observed difference in the EER’s between Spark-Ignited and HPDI natural gas combustion engines, Hydrogen BC would recommend that Table 4 include separate line items for *Natural Gas (High Pressure Direct Injection)* and *Hydrogen (High Pressure Direct Injection)*.

We would doubly recommend this because HPDI technology was first developed in British Columbia. If B.C. policies group a quantifiably superior, provincially-developed natural technology with an inferior legacy one, international observers will conclude that HPDI is no better than Spark-Ignition – when it actually is better. This would complicate discussions for the B.C. company, particularly with export markets.[6]

The slide below comes from a recent presentation by Westport for the SoCalGasEnergy Resource Centre in Downey, California, which will have been presented today (2022 Jan 31). Hydrogen BC understands that it shows the modelled efficiency of natural gas and hydrogen combustion systems. HPDI natural gas (third blue column) shows an improvement over Spark-Ignited natural gas (first blue column), and HPDI hydrogen is modelled to have an even greater improvement over the Spark-Ignited configuration.

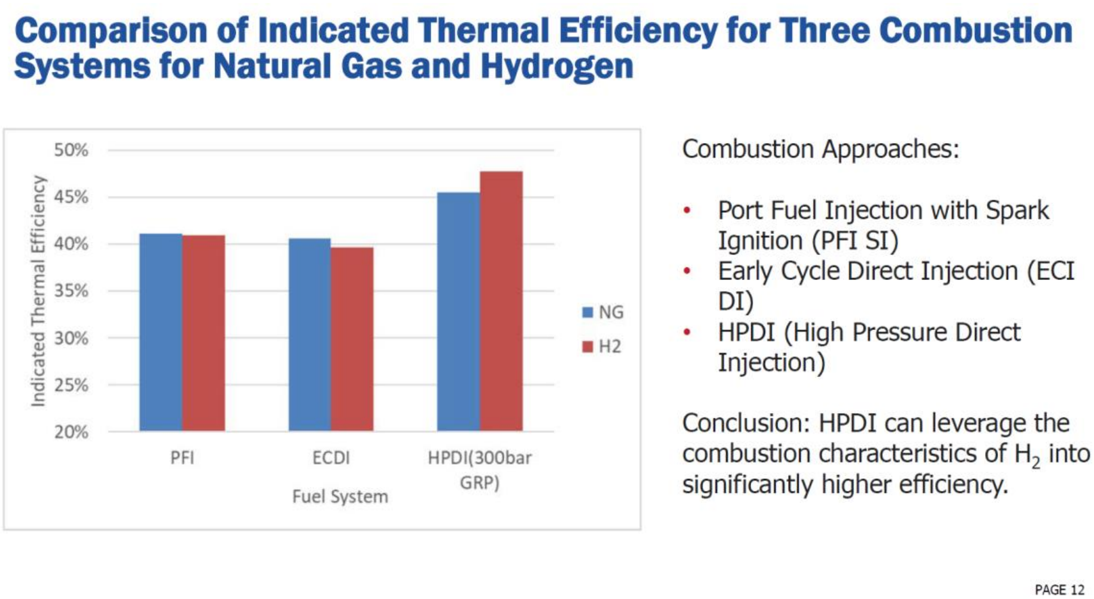

Figure H1. Modelled Thermal Efficiency for Selected Combustion Systems. Source: Westport

The Westport presentation shows engine test data indicating that at full power, the thermal efficiency of hydrogen HPDI was in the 46-47% range, as compared to 41-43% for natural gas

[6] A related example is how international visitors interpret Canada's lack hydrogen fuel cell heavy-duty vehicle deployments. The authors met with two Korean delegations on 2023 January 24. Both groups' first question was, "if Canada still has leading hydrogen fuel cell technology, why don't you have vehicles on the roads?". They interpreted the lack of deployment as a sign of technological inferiority. Not including HDPI-specific EER line items would be interpreted as the Province not believing it had technological superiority over Spark Ignition.

HPDI, as shown in Figure H2 below. This adds to the case for adding at least a separate line item for *Hydrogen (High Pressure Direct Injection)*.

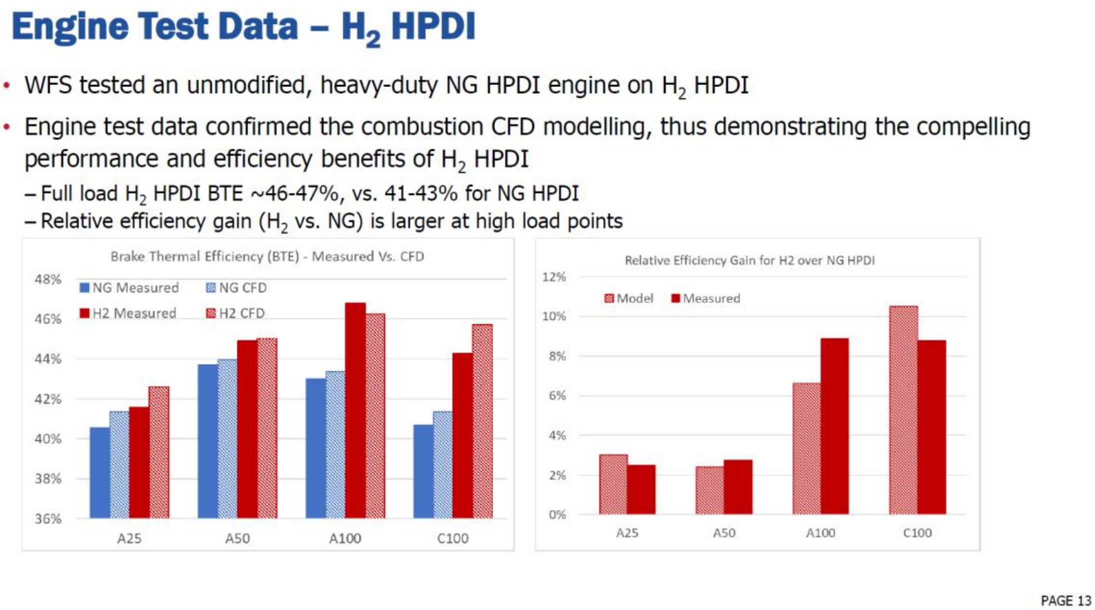

Figure H2. Thermal Efficiency Test Data for Selected Combustion Systems. Source: Westport

With the efficiency (eff) of natural gas HPDI estimated to be approximately 10% higher (being 45% versus 41%) than natural gas (Spark-Ignition) in Figure H1 its EER could be calculated as:

Natural Gas HPDI EER = Natural Gas (Spark-Ignition EER) *

(Natural gas (HPDI eff) / Natural Gas (Spark-Ignition eff))

= 0.90 * (0.45/0.41) = 1.0

The hydrogen HPDI EER calculation could draw from Figure H2, which shows an approximately 5% improvement in efficiency for hydrogen HPDI over natural gas HPDI (right-hand chart; mean measured efficiency gain between A25, A50, A100 and C100 conditions). The calculated EER for hydrogen HPDI could then be calculated as:

Hydrogen HPDI EER = Natural gas HPDI EER *

(Hydrogen HPDI eff / Natural Gas HPDI eff)

= 1.0 * (1.05) = 1.05

Reiterating the observed advantages of HPDI technology for both natural gas and hydrogen, Hydrogen BC strongly urges LCFB to include separate line items both for *Natural Gas (High Pressure Direct Injection)* and *Hydrogen (High Pressure Direct Injection)* with the estimated EER's calculated above.

Electricity (Gasoline Category)

The procedure for estimating the EER for electricity in the case of gasoline vehicles is given in Appendix E of the *Technical Intentions* paper, pp 26-29. In the first step of the calculation, data from 2011, 2016 and 2021 battery electric vehicles are used to calculate a preliminary EER of 3.46.

Hydrogen BC notes that the EER for 2011 was calculated on three entries, two of which were variants of the same vehicle; as a result, the smart fortwo has twice the weighting of the BMW Active E in the EER calculation. We would propose that the 2011 EER be amended so both vehicles have an equal weighting. This would result in a 2011 EER Combined of (4.64+2.42)/2 = 3.53. This is in line with the 2016 and 2021 figures.

The average of the 2011, 2016 and 2021 averages would then be (3.53+3.66+3.56)/3 = 3.59. After temperature adjustments the EER would be:

Temperature-Adjusted EER = 3.59 * (1-0.0137*10) = 3.1.

Given the complexities of automotive supply chains, it is appropriate for EER calculations not to attempt to correct for manufacturing emissions. As for the estimate that BEV manufacturing emissions are 70% to 100% larger than for equivalent internal combustion engine (ICE) vehicles, the multi-year trend has been for BEVs to incorporate ever-larger batteries each year. Over time the 70% to 100% figure could become an underestimate.

For example, the Nissan Leaf "grew" from 24 kWh to 40 kWh and 60 kWh. Even assuming generous battery energy density improvements, one would expect the 60 kWh Nissan Leaf to incur a higher manufacturing emissions penalty than the earlier 24 kWh model. One would expect still higher manufacturing emissions penalties for the Ford F-150 Lightning (which offers 98 kWh and 131 kWh battery options) over its ICE counterpart.[7]

Hydrogen Fuel Cell

The *Technical Intentions* paper proposes EERs for hydrogen fuel cell vehicles for both diesel (Table 4) and for gasoline (Table 5). The methodology is presented in Appendix E, pages 29-30.

In Table 14 the EER for light duty fuel cell electric vehicles (FCEVs) is calculated based on the Honda Clarity, Toyota Mirai and Hyundai Nexo. Despite Hydrogen BC and CHFCA's best efforts, the Honda Clarity FCEV has never been offered in Canada, so we would suggest it be removed from the Table.

Hydrogen BC additionally notes that the 1,848 kg Toyota Mirai used in Table 14 is the first-generation Toyota Mirai. The second-generation Toyota Mirai – the only version on sale in Canada – has a mass of 1,930 to 1,970 kg.[8]

Table 14 from the *Technical Intentions* paper shows a combined MPG for the first generation Toyota Mirai of 64 MPGe, consistent with figures widely cited online. The US EPA webpage for fuel cell vehicles shows three trim levels of the current Toyota Mirai, with combined MPGe's of 74 (LE trim), 65 (Limited trim), and 74 (XLE trim).[9]

At the present time only the Limited and XLE trims are available in Canada.[10] The average combined MPGe of those two models is then (74+65)/2 = 69.5 MPGe.

From the same webpage, the three current variants of the Lexus LS are shown to have combined fuel economies of 25 MPG, 22 MPG and 21 MPG respectively, for an average of (25+22+21)/3 = 22.7 MPG.[11]

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[7] The projected growth of LFP battery chemistry market share at the expense of NMC and NCA chemistries should somewhat mitigate this trend.

[8] Toyota Canada Mirai specifications page, accessed at https://www.toyota.ca/toyota/en/vehicles/mirai/models-specifications

[9] US Department of Energy, Office of Energy Efficiency and Renewable Energy and US Environmental Protection Agency, www.Fuel Economy.gov. The "Cars" tab must be selected. Accessed on 2023 Feb 02. https://www.fueleconomy.gov/feg/fcv_sbs.shtml

[10] Toyota Canada, accessed on 2023 Feb 02. https://www.toyota.ca/toyota/en/vehicles/mirai/models-specifications

[11] US Department of Energy, Office of Energy Efficiency and Renewable Energy and US Environmental Protection Agency, www.Fuel Economy.gov. Search result for 2023 Lexus LS. Accessed on 2023 Feb 02. https://www.fueleconomy.gov/feg/PowerSearch.do?action=noform&path=1&year1=2023&year2=2023&make=Lexus&baseModel=LS

The US DOE/EPA fuel economy webpage lists two variants of the Hyundai Nexo having combined MPGe's of 57 and 61, respectively.[12] The average combined MPGe of those two models is then (57+61)/2 = 59 MPGe.

From the same webpage, the non-hybrid versions of the current Hyundai Tucson are shown to have combined fuel economies of 28 MPG and 25 MPG respectively, for an average of (28+25)/2 = 26.5 MPG.[13]

Using this data Hydrogen BC would propose that a finalized Table 14 resemble something like Table H1 below. The average of the *EER, Combined* for the two FCEV models is (3.06/2.23) = 2.64.

Table H1. Preliminary Proposed EER for Light Duty FCEVs

Vehicle	Approx Weight (kg)	Combined MPG (or MPGe)	EER, Combined
Toyota Mirai (2nd generation)	1,950	69.5	3.06
Lexus LS (2023)	2,350	22.7	
Hyundai Nexo	1,850	59	2.23
Hyundai Tucson (2023)	1,500	26.5	

Hydrogen Fuel Cell - Mirai

It is valid to ask whether the Mirai/Lexus LS comparison is appropriate, given that the Lexus weighs considerably more than the Mirai. Hydrogen BC has proactively obtained information on Lexus' three sedan lines, the IS, ES and LS. These are presented in Table H2.

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[12] US Department of Energy, Office of Energy Efficiency and Renewable Energy and US Environmental Protection Agency, www.Fuel Economy.gov. The "SUVs" tab must be selected. Accessed on 2023 Feb 02. https://www.fueleconomy.gov/feg/fcv_sbs.shtml

[13] US Department of Energy, Office of Energy Efficiency and Renewable Energy and US Environmental Protection Agency, www.Fuel Economy.gov. Search result for 2023 Hyundai Tucson. Accessed on 2023 Feb 02. https://www.fueleconomy.gov/feg/PowerSearch.do?action=noform&path=1&year1=2023&year2=2023&make=Hyundai&baseModel=Tucson

Table H2. Data comparisons between Lexus Sedans

Vehicle	Approx Weight (kg)	Combined MPG	Data Sources (all accessed on 2023 Feb 02)
Lexus LS (2023)	2,350	22.7	See Table H1
Lexus IS (2023)	1,850	22.4 (avg of 20, 22, 22, 23, 25)	https://www.lexus.ca/lexus/en/automobiles/is/specifications https://www.fueleconomy.gov/feg/PowerSearch.do?action=noform&path=1&year1=2023&year2=2023&make=Lexus&baseModel=IS
Lexus ES (2023)	1,680	26.3 (avg of 25, 26, 28)	https://www.lexus.ca/lexus/en/automobiles/es/specifications https://www.fueleconomy.gov/feg/PowerSearch.do?action=noform&path=1&year1=2023&year2=2023&make=Lexus&baseModel=ES&srchtyp=ymm

Hydrogen BC would be amenable to the LCFB using the Lexus IS as a comparison to the Toyota Mirai owing to its closer weight, if that would be LCFB's preference. The Mirai's EER would then increase from approximately 3.06 to 3.10.

Hydrogen Fuel Cell - Nexo

With the Hyundai Nexo priced above $70,000 Hydrogen and positioned and accessorized as a luxury vehicle, BC has compiled statistics on the SUV's manufactured by Genesis, Hyundai's luxury division, in Table H3 below.

Table H3. Data comparisons between Genesis SUVs

Vehicle	Approx Weight (kg)	Combined MPG	Data Sources (all accessed on 2023 Feb 02)
Genesis GV70 (2023)	1,920 (1,820-2,010)	22.3 (avg of 21, 22, 24)	https://en.wikipedia.org/wiki/Genesis_GV70 https://www.fueleconomy.gov/feg/PowerSearch.do?action=noform&path=1&year1=2023&year2=2023&make=Genesis&baseModel=GV70
Genesis GV80 (2023)	2,170 (2,025-2,310)	21 (avg of 20, 22)	https://en.wikipedia.org/wiki/Genesis_GV80 https://www.fueleconomy.gov/feg/PowerSearch.do?action=noform&path=1&year1=2023&year2=2023&make=Genesis&baseModel=GV80

The Genesis GV70 is closest to the Hyundai Nexo in weight. Using its combined MPG as a comparator to the Nexo would result in an *EER, Combined* of (59/22.3) = 2.64.

Hydrogen Fuel Cell – Proposed EER Revisions

With the above updated analysis, Hydrogen BC would then propose EER's for light duty FCEVs available in the Province to be similar to that shown in Table H4.

Table H4. Hydrogen BC-Proposed EER for Light Duty FCEVs

Vehicle	Approx Weight (kg)	Combined MPG (or MPGe)	EER, Combined
Toyota Mirai (2nd generation)	1,950	69.5	3.10
Lexus IS (2023)	1,850	22.4	
Hyundai Nexo	1,850	59	2.64
Genesis GV70 (2023)	1,920	22.3	

The average *EER, Combined* for the two FCEVs would then be (3.10+2.64)/2 = **2.87**.

Given the still-minuscule level of FCEV adotion, Hydrogen BC does not believe the calculated *EER, Combined* figures for the first-generation Toyota Mirai in *Technical Intentions* paper Table 4 are relevant. If it is desired to include these, Hydrogen BC notes that in Table 14, the cited MPG for the Lexus LS (28 MPG combined) *only appears to reflect the single most fuel efficient model; the hybrid, non-AWD LS 500h.*

If hybrids were used as the comparators for BEVs in *Technical Intentions* paper Table 13, the calculated EER's for BEVs would be rather more modest. If Table 13 had used hybrids for EER comparisons where available, it would have included the Hyundai Ioniq with an EER combined of (120 BEV/57 hybrid) = 2.10.[14]

[14] US Department of Energy, Office of Energy Efficiency and Renewable Energy and US Environmental Protection Agency, www.Fuel Economy.gov. Search result for 2021 Hyundai Ioniq. Accessed on 2023 Feb 02. https://www.fueleconomy.gov/feg/PowerSearch.do?action=noform&path=1&year1=2021&year2=2021&make=Hyundai&baseModel=Ioniq

Since the Technical Intentions paper calculates BEV *EER, Combined* using non-hybrid combustion vehicles, it should use non-hybrid combustion vehicles for calculating FCEV *EER, Combined* as well.

If the *Low Carbon Fuels Branch* strongly desires to include first-generation Toyota Mirai data in its EER, Combined calculation for light duty FCEVs, Hydrogen BC notes that the non-hybrid Lexus LS fuel economy data for the roughly representative model years (2016 through 2020) comprises trim levels with combined economies of 21, 23, 23 and 23 MPG, the mean of which is 22.5 MPG.[15]

The first-generation Toyota Mirai would then have an *EER, Combined* of (64/22.5) = 2.84.

The inclusion or exclusion of this revised *EER, Combined* would not have a material impact on subsequent calculations.

Hydrogen Fuel Cell – Temperature De-rate

It is important to reflect that British Columbia experiences colder temperatures than those evaluated in standardized fuel economy tests. To that end the *Technical Intentions* paper uses data from the Norwegian Automobile Association and Motor magazine, to estimate an increase in energy consumption for BEVs of +1.37% per 1°C temperature reduction.

The *Technical Intentions* paper converts EER estimates the increase in BEV energy consumption going from 20°C testing conditions to Vancouver's average 10°C conditions as (0.0137/°C)*10°C = 0.137 or 13.7%.

The *Technical Intentions* paper also references the 2019 study by Henning et al, which attempts to quantify the effect of fuel consumption on FCEBs and BEBs.[16] An 18% reduction in EER was estimated for FCEVs.[17]

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[15] US Department of Energy, Office of Energy Efficiency and Renewable Energy and US Environmental Protection Agency, www.Fuel Economy.gov. Search result for 2016-2020 Lexus LS. Accessed on 2023 Feb 02. https://www.fueleconomy.gov/feg/PowerSearch.do?action=noform&path=1&year1=2016&year2=2020&make=Lexus&baseModel=LS

[16] Henning, Mark; Thomas, Andrew R.; and Smyth, Alison. 2019. "An Analysis of the Association between Changes in Ambient Temperature, Fuel Economy, and Vehicle Range for Battery Electric and Fuel Cell Electric Buses". Urban Publications. 0 1 2 3 1630. https://engagedscholarship.csuohio.edu/urban_facpub/1630

[17] *Technical Intentions* paper, Page 30.

This appears to be based on Table 4 of the Henning study, where tree FCEB-operating transit agencies found that a 1°F decrease in ambient temperature corresponded to fuel consumption increases of 0.57%, 1.28% and 1.16%, respectively. The mean of these three figures is a 1.00% increase in fuel consumption per °F below ambient temperature, which corresponds to a 1.81% (1.8% with rounding) increase in fuel consumption per °C below ambient temperature.

It is important to consider that whereas the earlier 1.37% figure reflects the observed fuel consumption increase for light duty BEVs, the 1.81% figure reflects the observed fuel consumption increase for **FCEBs** (not light duty FCEVs).

Table 5 of the Henning study also calculates the fuel consumption increase for BEBs. Here transit agencies found a mean fuel consumptiuon increase per 1°F decrease in ambient temperature for BEBs of 2.10%, 0.81%, 0.33% and 1.51%. The mean of these four figures is a 1.19% increase in fuel consumption per °F below ambient temperature, which corresponds to a 2.14% increase in fuel consumption per °C.

Hydrogen BC wishes to emphasize that in the Henning study fuel cell electric bus fuel consumption increased *less than* battery electric buses in colder temperatures: 1.81%/°C versus 2.14%/°C. We strongly expect a similar pattern to hold for FCEVs as compared to BEVs. If nothing else, fuel cell electric vehicles can use the fuel cell byproduct exhaust heat for cabin heating.

In the absence of large-scale data, Hydrogen BC would propose the assumption that the ratio of FCEV/BEV range loss in cold temperatures is the same as the ratio of FCEB/BEB range loss:

FCEV/BEV % range loss = FCEB/BEB range loss.

Assumed FCEV range loss in colder tempeatures could then be calculated as:

FCEV range loss in cold temperatures = (FCEB/BEB range loss) * (BEV range loss)

Using the above figures results in the following calculation:

FCEV % range loss (from 20°C to 10°C) = (1.81/2.14) * (13.7) = 11.6%

The non-temperature-corrected *EER, Combined* for FCEVs from Table H4 is 2.87. Reducing this quantity by 11.6% results in a temperature-corrected *EER, Combined* for FCEVs of:

Temperature-corrected EER for FCEVs = 2.87 * (1 - 11.6/100) = 2.87 * 0.884 = 2.54.

If the LCFB wishes to adhere to two significant digits, this would round down to 2.5.

Hydrogen Fuel Cell EER for Gasoline and Diesel

Drawing from updated vehicle data and relevant comparison vehicles, and closely reviewing the source material relied upon by the *Technical Intentions* paper, Hydrogen BC proposes that EER for hydrogen fuel cell vehicles for the gasoline class be updated from 1.8 to 2.5.

The *Technical Intentions* paper uses the same 1.8 estimate as the Hydrogen EER for diesel. We recommend revising this to 2.5 as well.

Based on the available data this newer EER will more accurately reflect the EER that BC drivers will observe in their driving.

Conclusion

Hydrogen BC is appreciative of the opportunity to provide feedback to the Low Carbon Fuels Branch and its *Technical Intentions* paper.

Based on the inclusion of newer data and other attempts to ensure the Proposed EER is as representative as possible to the probable experience of drivers in British Columbia, Hydrogen BC recommends that:

- Guardrails and other measures be considered for LCFA credits, to ensure B.C. avoid California's experience of collapsing credit prices;
- Natural gas (HPDI) and Hydrogen (HPDI) line items be included in EER tables;
- Natural Gas (HPDI) EER be set at 1.0;
- Hydrogen (HPDI) EER be set at 1.05;
- Electricity (Gasoline Category) be revised from 3.0 to 3.1;
- Hydrogen Fuel Cell Vehicle (Gasoline Category) be revised from 1.8 to 2.5;

- Hydrogen Fuel Cell Vehicle (Gasoline Category) be revised from 1.8 to 2.5.

These represent Hydrogen BC's best-efforts approach to calculate relevant, representative EER's based on the most up to date data available.

Hydrogen BC remains available at the Low Carbon Fuels Branch's convenience to discuss our methodologies and assumptions. We appreciate the LCFB's flexibility and openness to receiving a late response on account of the passing of one of the parents of the key author, and remain committed to responding within specified timeframes in all future correspondence.