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Well-to-Wheels Energy and Greenhouse Gas Emission Analysis of Bio-Blended High-Octane Fuels for High-Efficiency Engines

Appendix 6 – The Comparison of E Set Domestic Gasolines and BR Set Domestic Gasolines

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Figures

Table

Among the E set gasolines, F15 and F19 show the greatest GHG emission reductions relative to baselines (the domestic business−as−usual E10 gasoline produced from base cases), while among the BR set gasolines, BR2/BR2-T and BR4-T demonstrate the greatest potential to reduce GHG emissions. Their GHG reduction potential is greatly determined by their high level of bio-blendstock, coupled with their high RON numbers enabling fuel economy gains (for per mile basis).

With different bio-blendstock type and different technology for bio blendstock production, the F15 and F19 domestic gasoline are compared with BR2 and BR4-T domestic gasoline in terms of energy uses and GHG emissions, taking the examples in PADD 3 in 2040.

With 30 vol% ethanol in F15 and F19, and 27 vol% bioreformate in BR2 and BR4-T, their BOB and bio-blendstock energy shares are shown in the table below.

Table A6-1. The Energy Shares of E Set and BR Set Domestic Gasolines in 2040 (all HOF)

2040 Domestic Gasoline	BOB Energy Share (%)	Bio-blendstock Energy Share (%)	Total
F15	77.6%	22.4%	100%
F19	77.4%	22.6%	100%
BR2/BR2-T	70.3%	29.7%	100%
BR4-T	70.7%	29.3%	100%

With similar volumeric blending, relative to BR2 and BR4-T, F15 and F19 have higher energy shares from gasoline BOB and lower bio-blendstock energy shares, owing to the lower low heating values (LHV) of ethanol.

The WTW energy uses (per MJ domestic gasoline) of these four fuels (F15, F19, BR2 and BR4-T) are shown in the figure below.

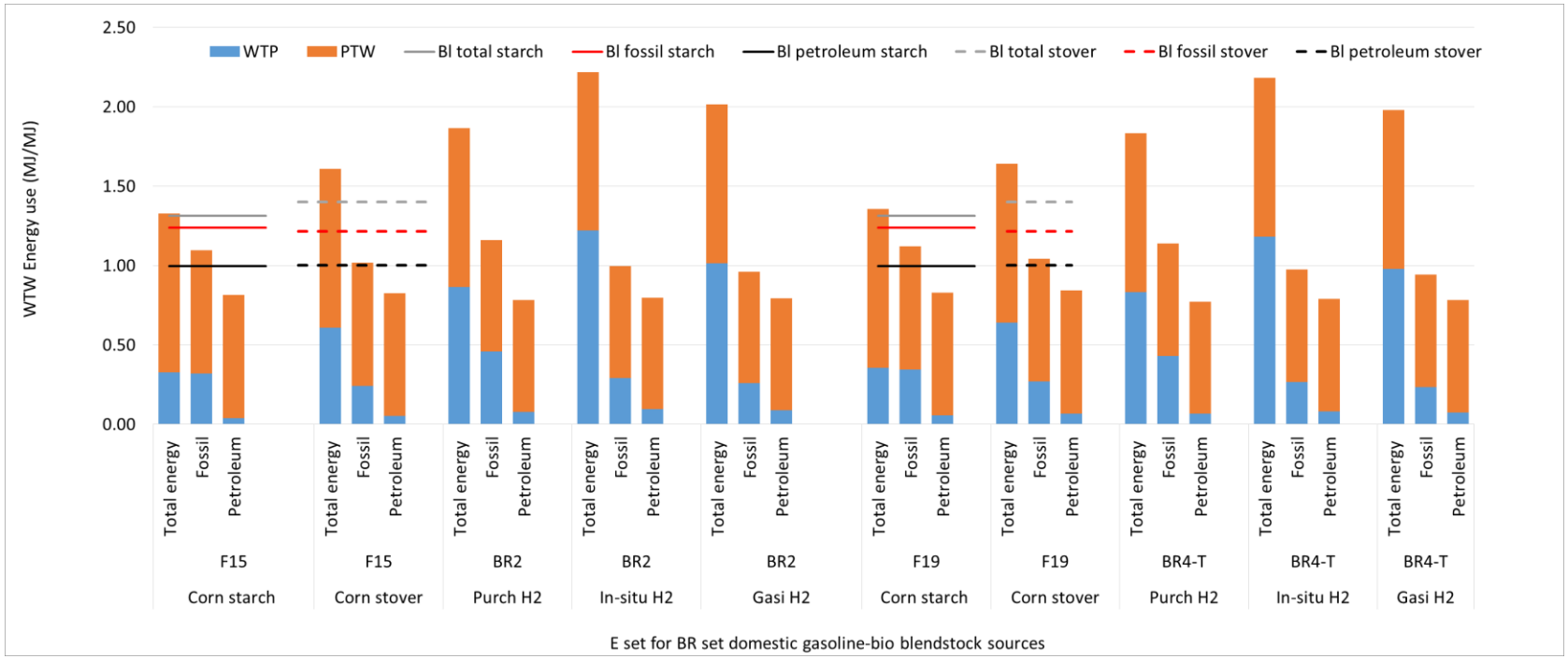

Figure A6-1. The WTW Energy Uses of F15/F19 and BR2/BR4-T Domestic Gasolines in PADD 3 in 2040 Per MJ Basis

With similar volumeric bio-blendstock blending, the BR set gasolines (regardless the hydrogen source) consume more total energy than E set gasolines (regardless the ethanol source). For fossil energy, the BR fuels with renewable hydrogen (in situ hydrogen and gasification hydrogen) consume less energy than BR fuels with purchased hydrogen and E set fuels with corn starch/corn stover ethanol. In terms of petroleum energy, all five options consume similar amount of energy.

The GHG emissions per MJ are compared in the figure below to evalualte the environment impact by using E set domestic gasoline and BR set domestica gasoline.

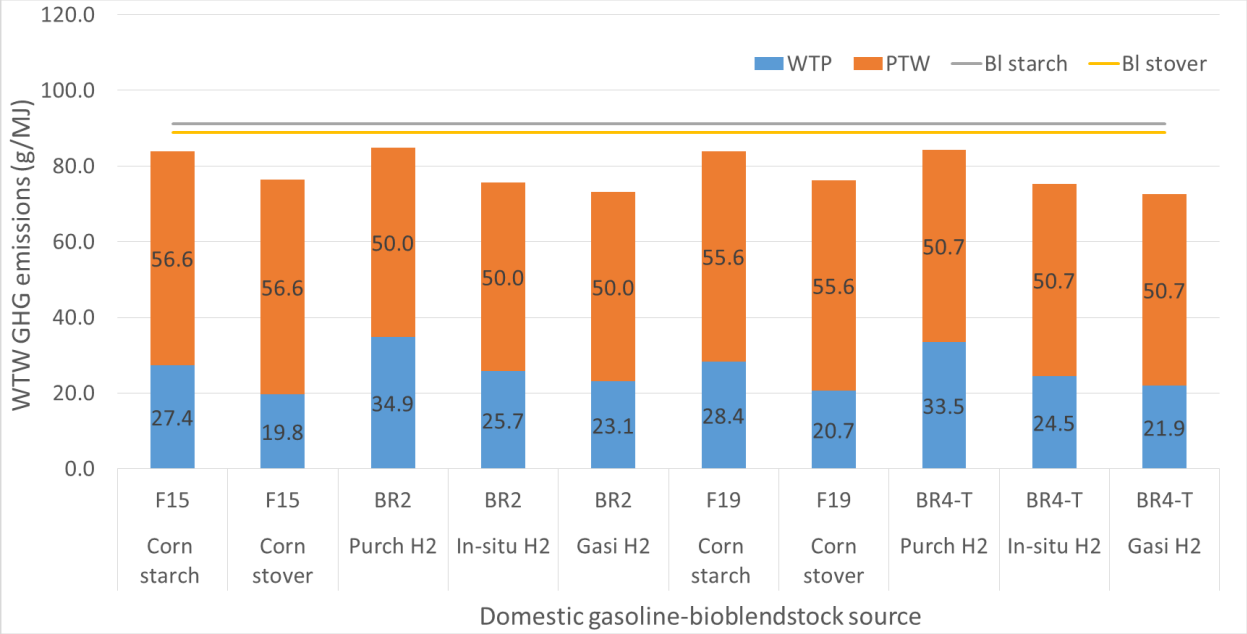

Figure A6-2. The WTW GHG Emissions of E Set Domestic Gasoline and BR Set Domestic Gasoline in PADD 3 in 2040 (all HOF), Per MJ Basis

As stated previously E set gasoline with corn stover ethanol and BR set gasoline with gasification hydrogen have lower GHG emissions than the domestic gasolines produced with other bio-blendstock sources/production technology (corn starch ethanol, bioreformate with purchased hydrogen and in-situ hydrogen). The GHG emission variation in WTP stage is greater than the variation in PTW stage, revealing the importance of reducing WTP GHG emissions, although the WTP stage is generally less dominant than PTW stage. All the F15/F19, BR2/BR4-T domestic gasolines with various bio-blendstock options have lower GHG emissions relative to the duel baselines (E10 gasoline with corn starch ethanol and corn stover ethanol, respectively). The GHG reduction relative to baselines are shown in the figure below.

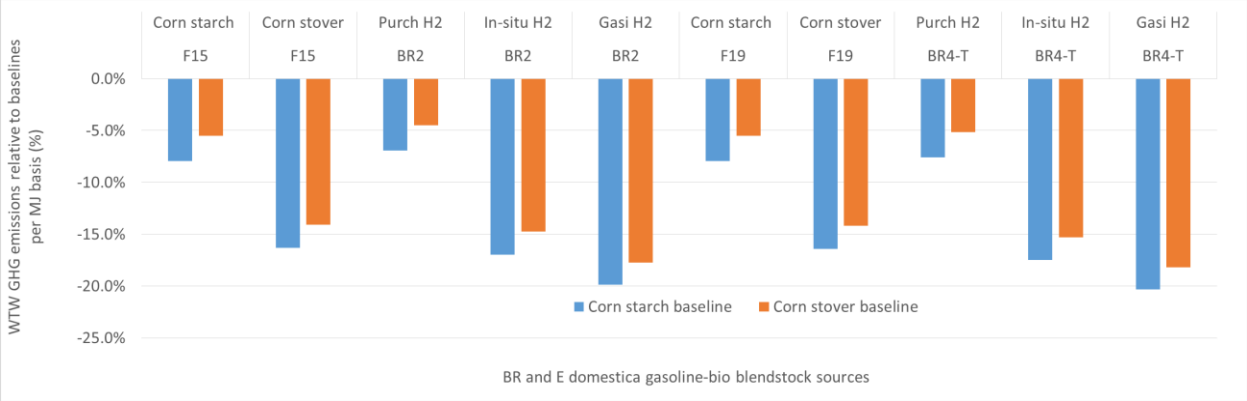

Figure A6-3. The Comparison of E Set Domestic Gasoline and BR Set Domestic Gasoline WTW GHG Emissions with Baselines in PADD 3 in 2040 (all HOF)

Compared to baselines with either corn starch ethanol or corn stover ethanol, BR2 and BR4-T domestic gasolines (with gasification hydrogen) show greatest GHG emission reductions. The difference of GHG reduction (per MJ basis) between BR2 and BR4-T is small, about less than 1%.

It is worth mentioning that the LP modeling of BR4-T cases uses toluene as a surrogate for bioreformate to achieve feasible solutions. The underlining assumption is that bio-toluene is produced by consuming the same amount of energy and emitting the same amount of GHG as bioreformate is. This likely underestimate the WTP energy use and GHG emissions of BR4-T by omitting the (hypothetical) energy use and GHG emissions during separation stage (separating biotoluene from bioreformate). However, this impact is expected to be small because the hydrogen production and conversion process is likely to be much more dominant in energy use and GHG emissions than a separation process.

The differences of energy use and GHG emissions between F15 and F19, BR2 and BR4-T are small per MJ basis, with similar bioblendstock blending levels. However, the difference is more pronounced on per mile basis, shown in the figure below.

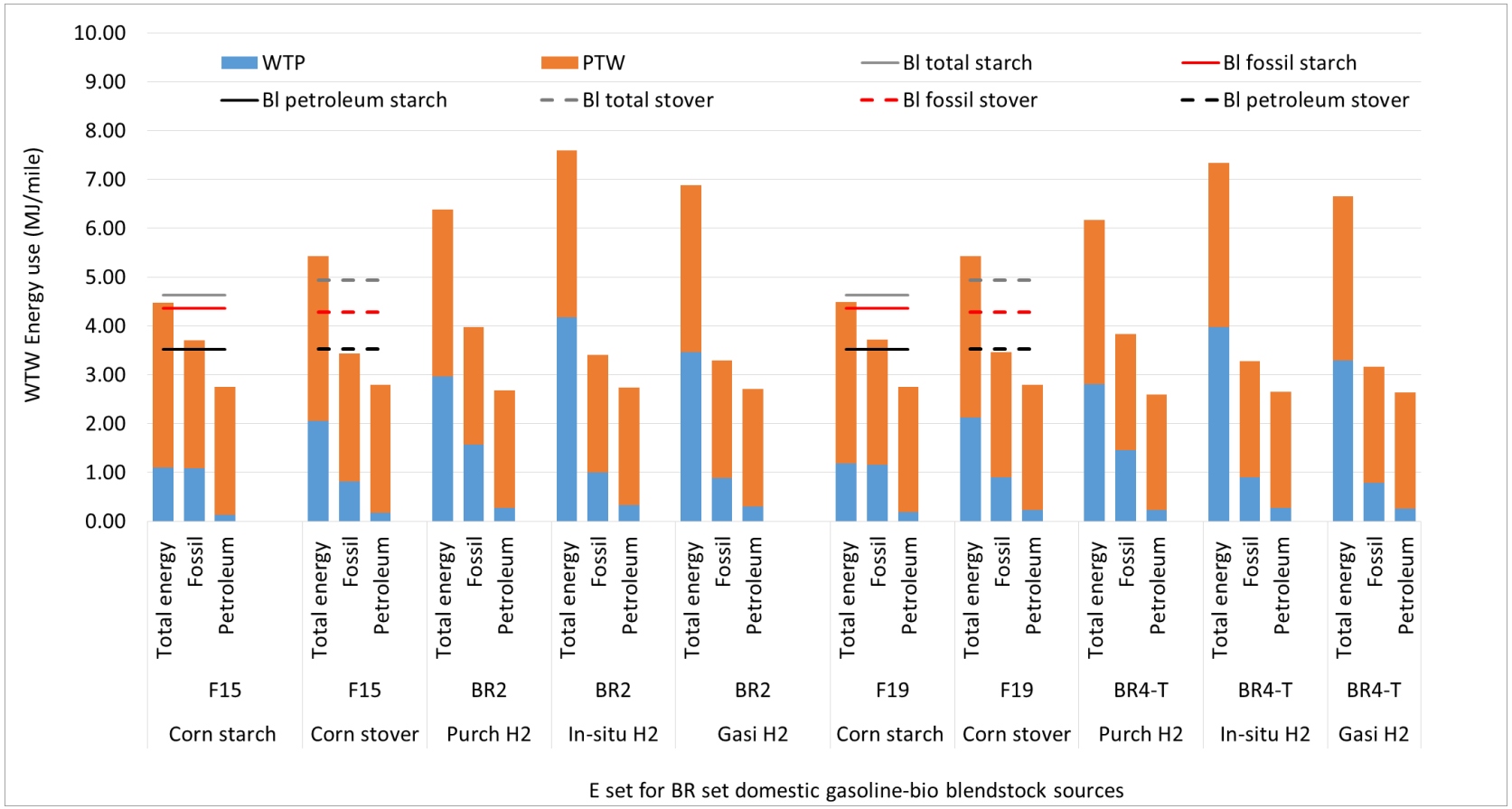

Figure A6-4. The WTW Energy Uses of F15/F19 and BR2/BR4-T Domestic Gasolines in PADD 3 in 2040 Per Mile Basis, with 3.0 ON/CR Assumption

With the fuel economies derived from 3.0 ON/CR assumption, the high RON (101) gasoline of F19 and BR4-T has less energy uses per mile basis than mid RON gasoline of F15 and BR2. Relative to the energy uses of duel baselines (ethanol from corn starch and from corn stover, respectively), the F15/F19 and BR2/BR4-T domestic gasolines use much higher total energy (except for F15/F19 with corn starch ethanol), much lower fossil energy and much lower petroleum energy. Comparing F15/F19 and BR2/BR4-T reveals that the BR domestic gasolines use much higher total energy than E set domestic gasolines. The WTW GHG emissions of the four gasolines with various bio-blendstock sources are shown in Figure A6-5.

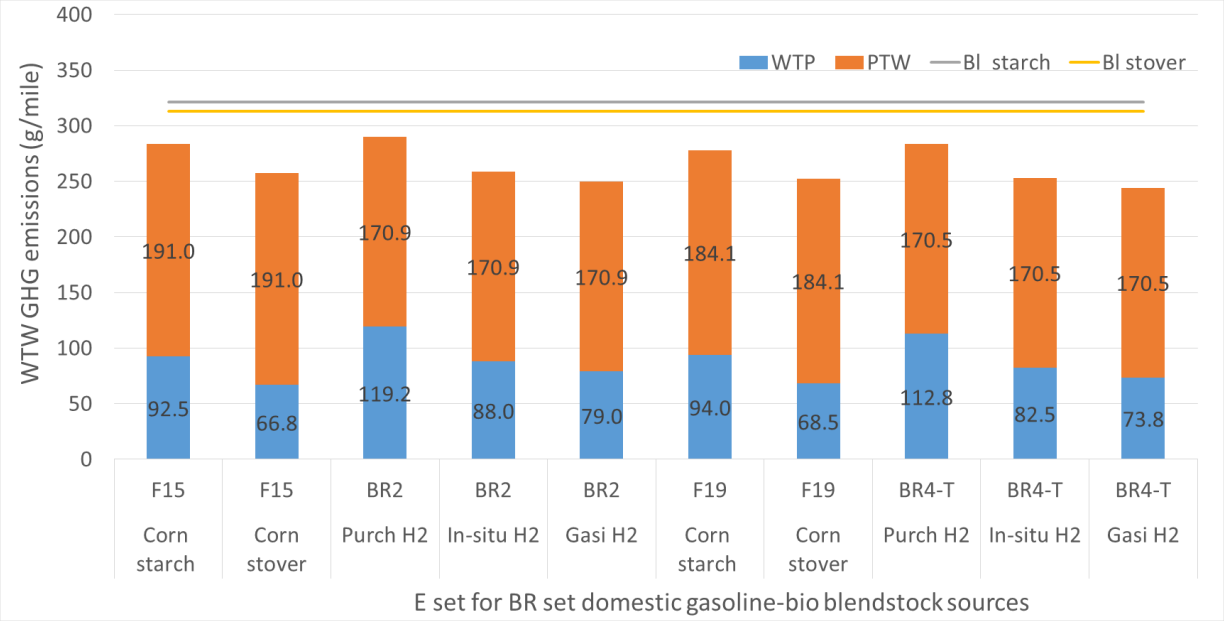

Figure A6-5. The WTW GHG Emissions of E Set Domestic Gasoline and BR Set Domestic Gasoline in PADD 3 in 2040 (all HOF), Per Mile Basis

As stated earlier, the GHG emission variation in WTP stage is more pronounced than that in PTW stage. The former can reach about over 40-50 g/mile, while the latter is about 10-20 g/mile. Overall, per mile basis, although the BR2/BR4-T domestic gasolines have higher GHG emissions at WTP stage than F15/F19 domestic gasolines, their PTW stage has lower GHG emissions (owing to their higher bio-carbon content) than the latter, resulting a lower WTW GHG emissions than the latter. The comparisons of GHG emissions of these four gasolines with baselines are shown in Figure A6-6, for per mile basis.

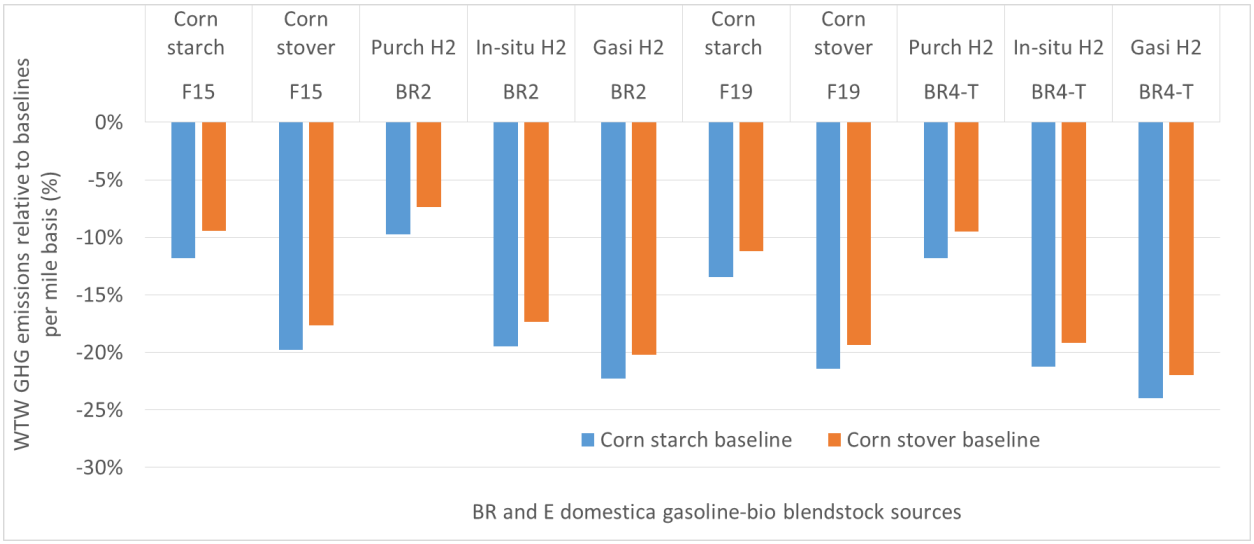

Figure A6-6. The Comparison of E Set Domestic Gasoline and BR Set Domestic Gasoline WTW GHG Emissions with Baselines in PADD 3 in 2040 (all HOF), Per Mile Basis

By accouting for the fuel enomomy gains enabled by the high octanes, BR4-T with gasification hydrogen shows the greatest GHG reductions, about 24% reduction relative to baseline with corn starch ethanol, and 22% reduction relative to baseline with corn stover ethanol. With mid RON of 97, BR2 shows slightly greater GHG emissions reduction than high RON gasoline of F19, owing to its higher bio-content, but the difference is very small. Overall, BR4-T gasoline with gasification hydrogen, BR2 with gasification and F19 with corn stover ethanol show great GHG reduction along the WTW life cycle, about 22-24% relative to baseline with corn starch ethanol, and about 19-22% relative to baseline with corn stover ethanol.

Overall, for both per MJ and per mile basis, BR4-T and BR-2 show large WTW GHG reduction (more than 20%) relative to duel baselines in 2040, greater than F15/F19 which have similar bio-blendstock shares, especially, BR4-T has the most reduction per mile owing to its high RON.