OnLocation
A KEYLOGIC COMPANY

# Analysis of API's Climate Framework:

## *API22-NEMS Results for Revised Federal Carbon Reduction Standard Case*

**Prepared for API**

September 7, 2022

*CLIENT CONFIDENTIAL*

# Outline

- Introduction
- Revised Scenario definition
- Modeling results and observations
- Next steps
- Appendix of additional information

# Introduction

- API is interested in exploring the effects of a federal carbon reduction standard (FCRS) that would reduce $CO_2$ emissions from transportation fuels.
- OnLocation used the API22-NEMS[1] model to create a customized reference case for API that includes policy updates that have occurred since the EIA's Annual Energy Outlook (AEO) 2022 was published.
  - Power and $CO_2$ capture provisions of Infrastructure Investment and Jobs Act (IIJA)
  - Updated NHTSA CAFE standards through 2026
  - Updated state level Zero Emission Vehicle policies (including 100% sales by 2050 for CA)
- We have modified the API22-NEMS to include the capability to represent the FCRS policy in a similar manner as the California low carbon fuel standard (LCFS).
- This slide deck presents results of an FCRS case with revised assumptions after our initial test case.

[1] *API22-NEMS is a modified version of the U.S. Energy Information Administration's National Energy Modeling System (NEMS) developed by OnLocation for use in this analysis that is based on the AEO 2022 version of NEMS. For more information about the NEMS model and the AEO projections, visit https://www.eia.gov/outlooks/aeo/.*

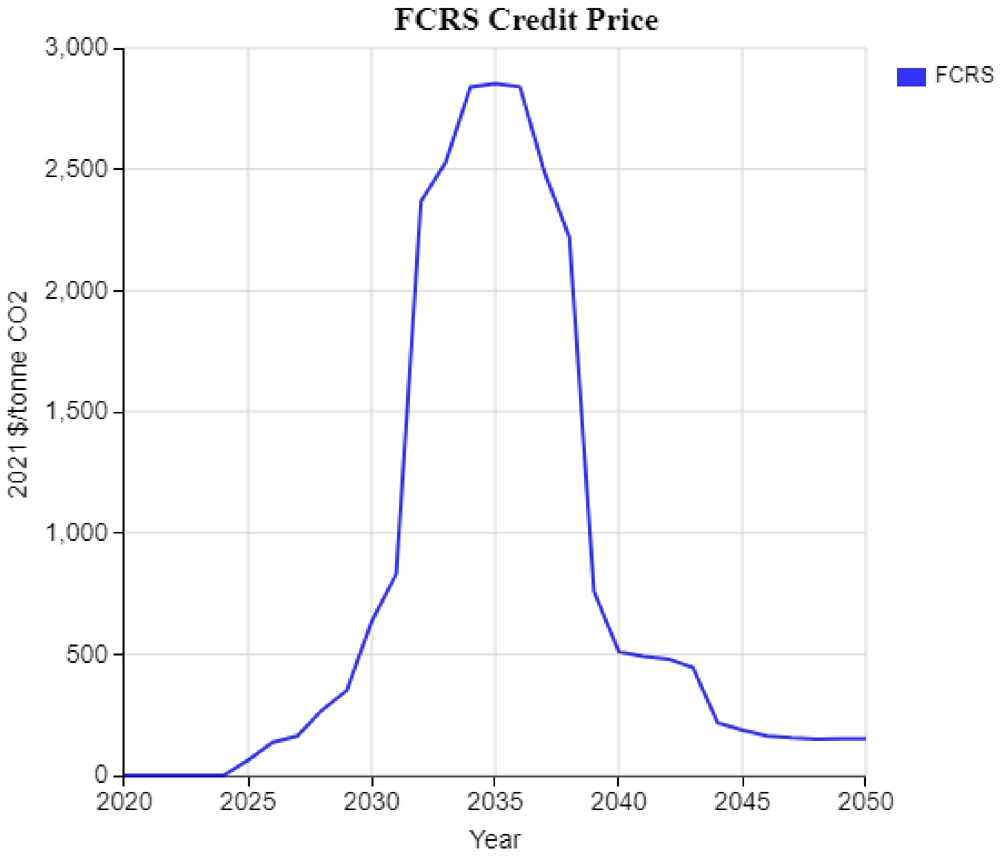
# Revised FCRS Case Definition

- FCRS covers gasoline and diesel fuels with individual annual standards and credit trading (combined standard) with no banking of credits
- Carbon intensity (CI) requirement declines by 1 percent per year for 15 years starting in 2023
- The FCRS cost containment price was set to $10,000 per tonne $CO_2$ (designed to be non-binding)
- Carbon factors except electricity and selected other fuels are assumed to be the same as those used for the California LCFS except
  - The carbon factor for electricity set equal to the national average carbon intensity for electricity used in transportation using an EER of 3.4 included for electricity
  - Carbon intensities for corn ethanol, pyrolysis, FAME biodiesel and renewable diesel were modified to reflect values provided by ExxonMobil with CIs for corn ethanol and processes using soy oil declining by 5% per year through 2027 (note that the EM factors decline for 14 years but assume carbon capture for ethanol, and we felt it is unrealistic to assume continuing declines without any cost)
- The maximum shares for E15 were increased to allow 100% shares by 2027
- Agricultural portions of the biomass curves were shifted to reflect the NREL 2016 Billion Ton Study
- AEO 2022 reference case biofuel production costs were assumed
- Advanced biofuels capacity maximum growth rates have been increased relative to the default model
- Existing policies, including California LCFS and RFS standards as represented in the AEO 2022 with relatively constant targets, assumed to remain in place

** Note, all monetary values in this analysis are expressed in real 2021$ unless otherwise indicated.*

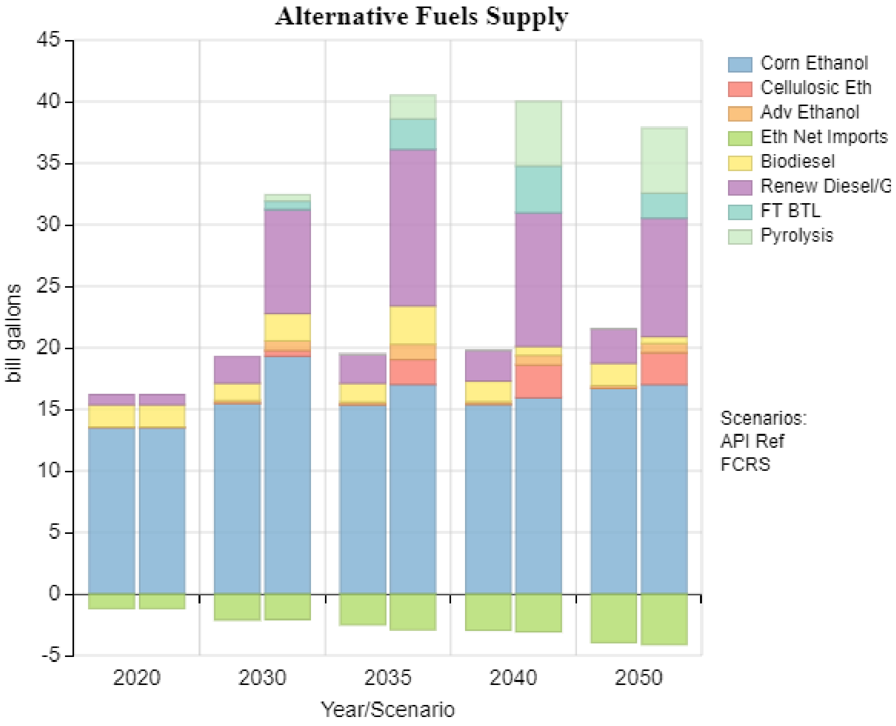
# FCRS Credit Price

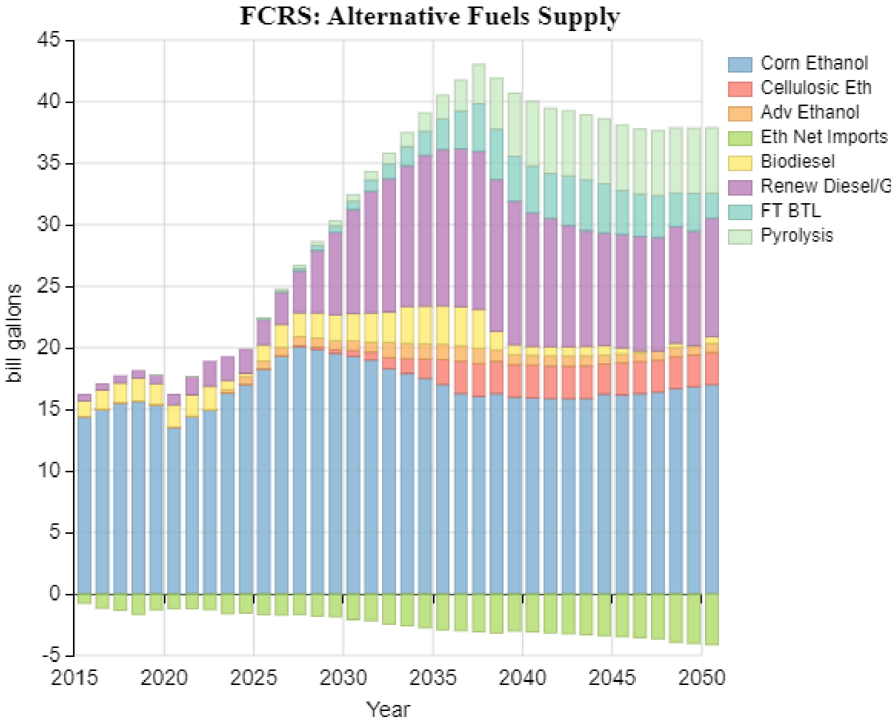
- The FCRS requirements are met in all years.
- The FCRS credit price rises quickly and rises to almost $2490 per tonne CO2 in 2037.
- The price is zero in the first two years of the program (2023-2024) as the increase in E15 sales along with the decreases in carbon intensity of corn ethanol and biofuels are sufficient to meet the target.
- After 2037 when the target stringency is constant, the credit price falls and returns to $150, as biofuels production drops a little, and expensive soy oil and imported biodiesel are reduced.



# Biofuels Supply

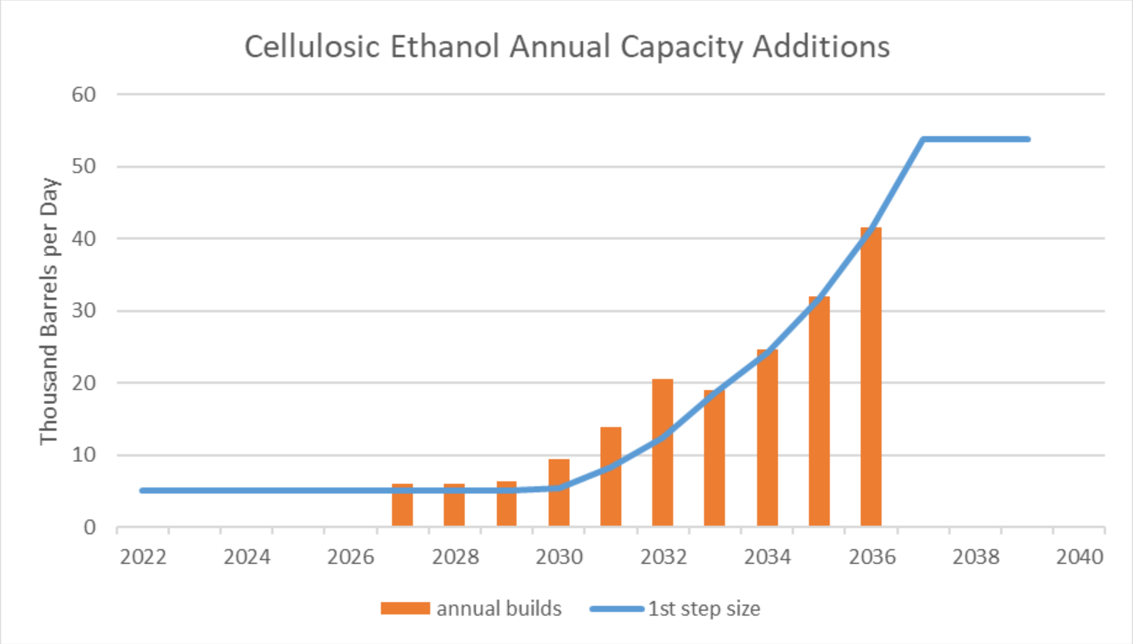
- With a combined standard, biofuel replacements for diesel play a larger role than gasoline substitutes. There is an initial shift to greater corn ethanol blending as E15 sales increase and then a shift to renewable diesel, Fischer-Tropsch (FT) liquids and pyrolysis.
  - After 2037, renewable diesel, biodiesel, and FT liquids decline while pyrolysis and cellulosic ethanol remain relatively constant.



# Biofuel Growth Rate Constraints

- Second-generation biofuels, such as cellulosic ethanol, pyrolysis, and Fischer-Tropsch liquids (FT BTL) have constraints in the model that govern their expansion rates, and these are active in the FCRS case.
  - An initial maximum plant build along with a maximum growth rate relative to prior year cumulative capacity defines what can be built without paying a higher capital cost and a cost penalty multiplier.
  - These maximum growth rates have been expanded from 20% without a cost penalty to 25% for FT BTL and BPU and to 30% for cellulosic ethanol. In addition, the second step size was doubled for cellulosic ethanol.

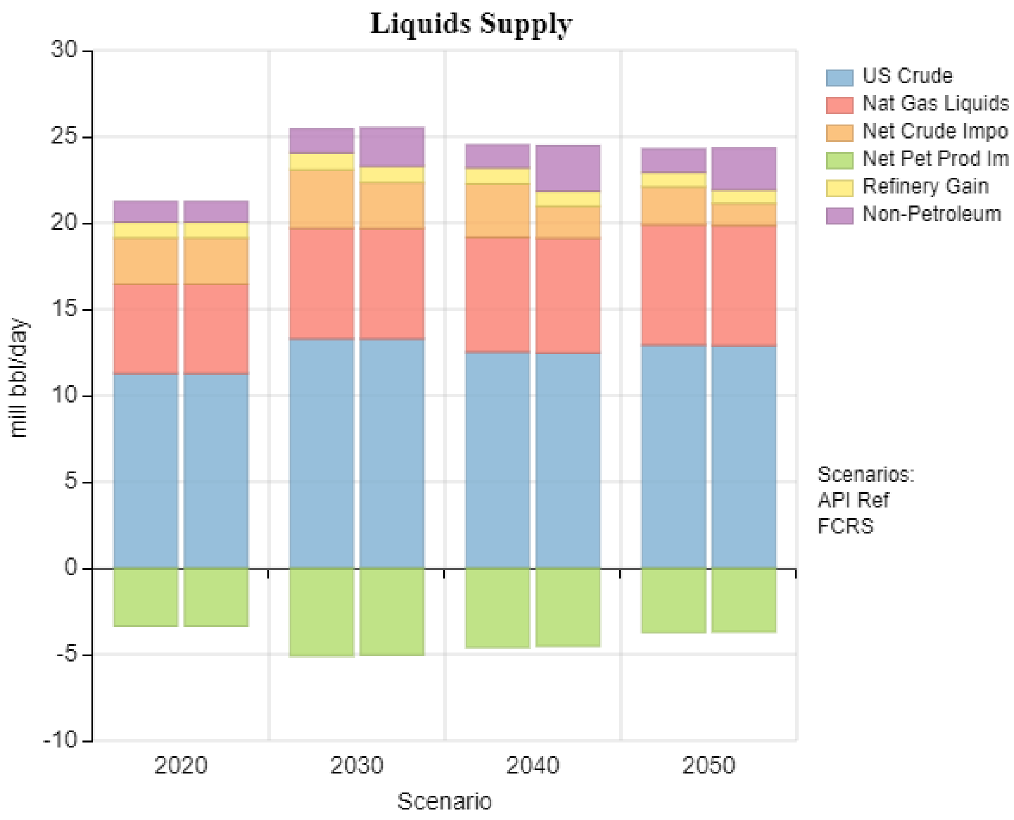


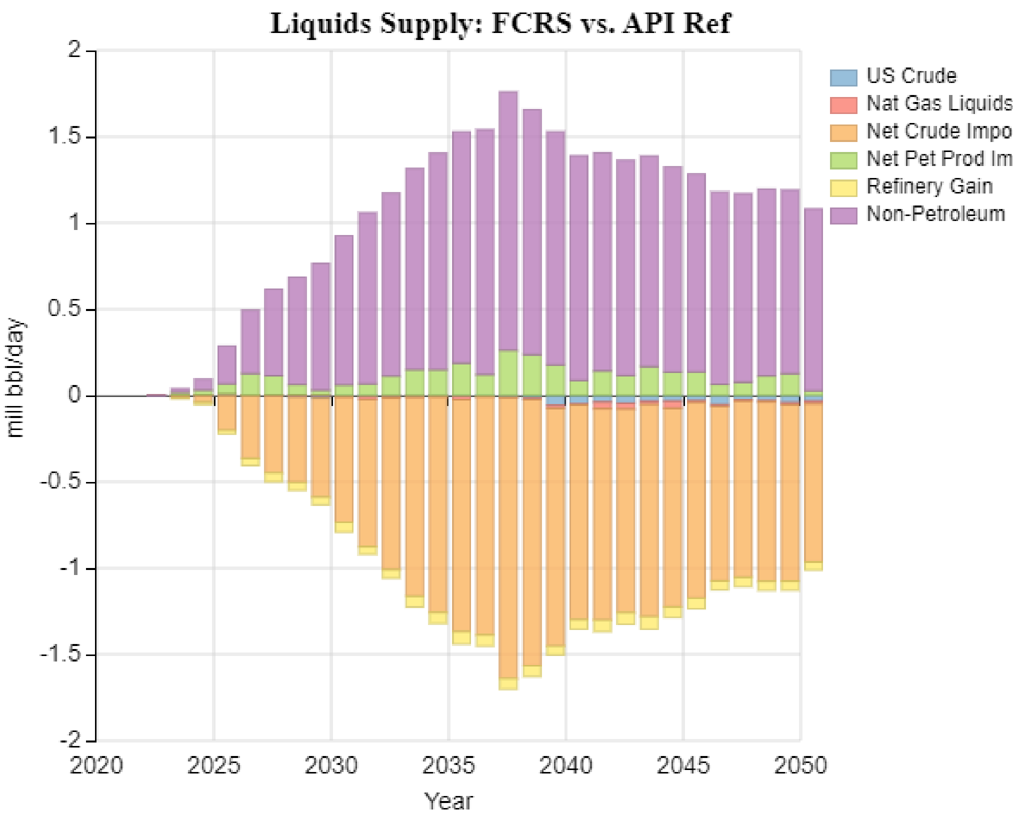

**Cellulosic Ethanol Growth Assumptions**

| | Step 1 | Step 2 | Step 3 |
|---|---|---|---|
| **Reference Case** | | | |
| Capacity Increases | 20% | 6% | 3% |
| Cost multipliers | 100% | 150% | 500% |
| | | | |
| **Revised FCRS Case** | | | |
| Capacity Increases | 30% | 18% | 5% |
| Cost multipliers | 100% | 150% | 500% |

# Liquid Fuel Supply

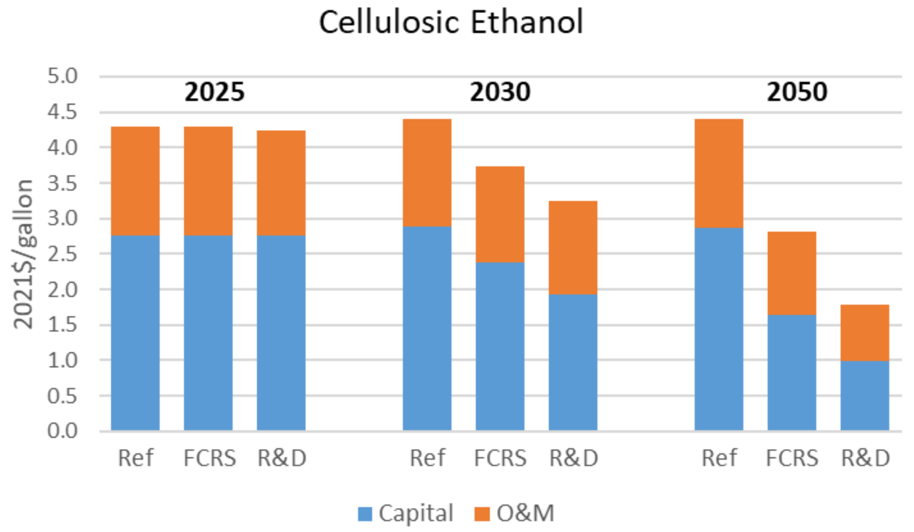
- Increased biofuels primarily displaces crude oil and reduces the throughput at U.S. petroleum refineries.  Net petroleum product imports increase slightly as well.

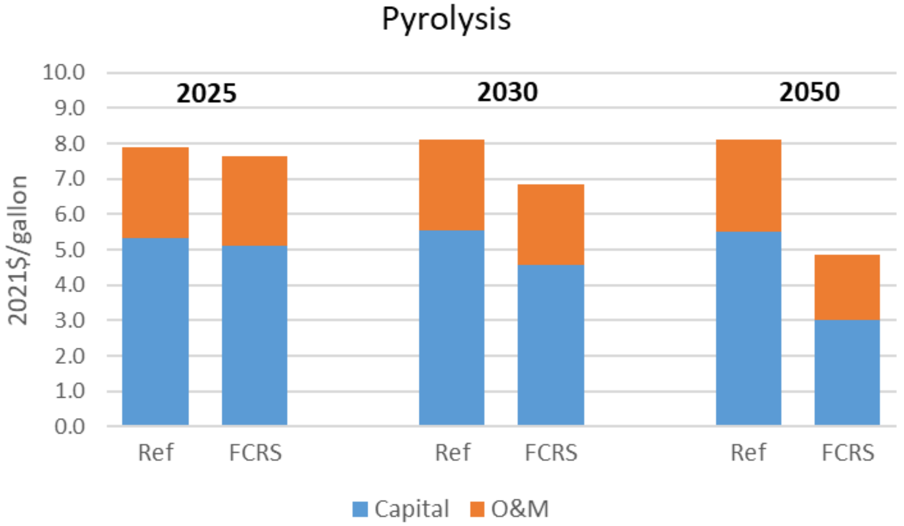


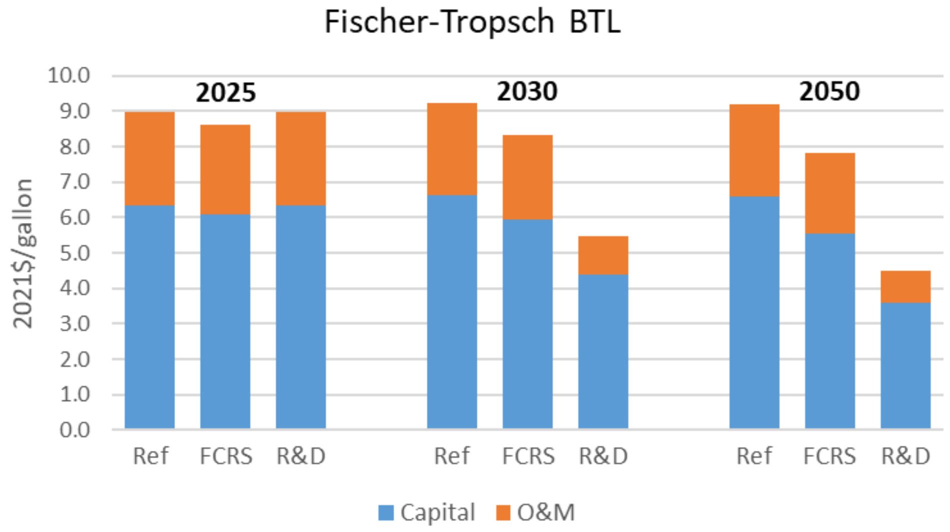



# Biofuel Costs with Learning

- The cost of second-generation biofuels decline through learning-by-doing as production capacity expands.
  - Long run costs remain higher than in the API22-NEMS $CO_2$ Price case where additional R&D was assumed to reduce these costs starting in 2030 (see Appendix).



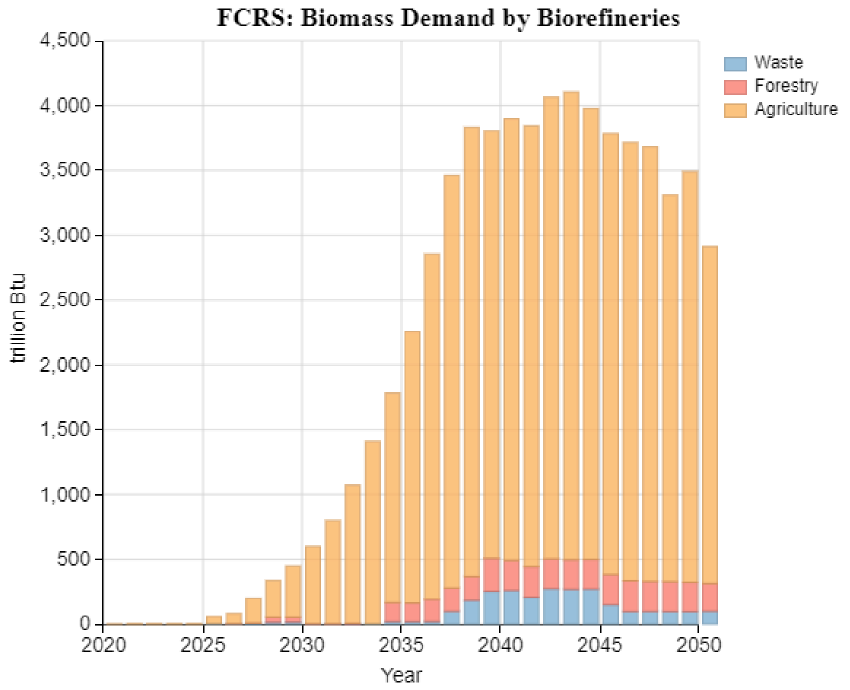



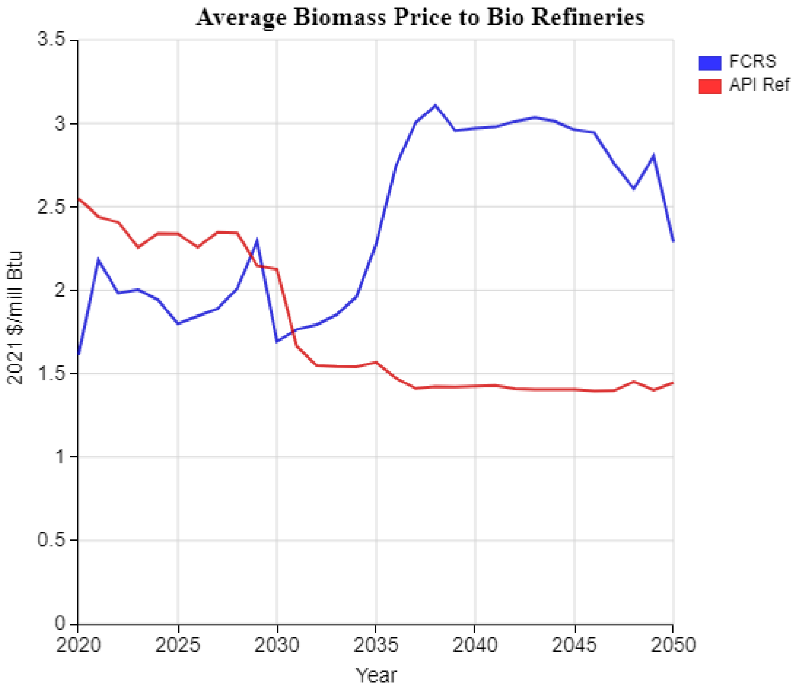



*Note the difference in scale in the Cellulosic Ethanol chart.*

# Biomass Consumption and Prices

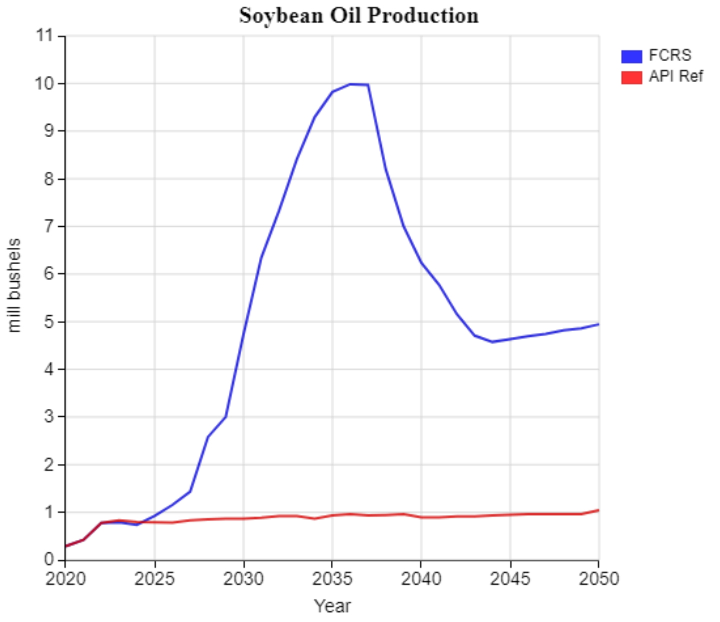
- As biomass use as a biofuel feedstock rises, so do biomass prices even though the supply curves are assumed to shift over time with more supplies becoming available.
  - The FCRS case prices reflect the use of fixed supply curves where agricultural resources (the primary source) were modified to reflect the curves from the NREL 2016 Billion Ton Study which assume more biomass is available at higher prices than do the native assumptions in API22-NEMS that use a reduced form of the Polysys model.
  - In the long run, biomass use tapers down due to declining gasoline and diesel consumption and a constant FCRS requirement.

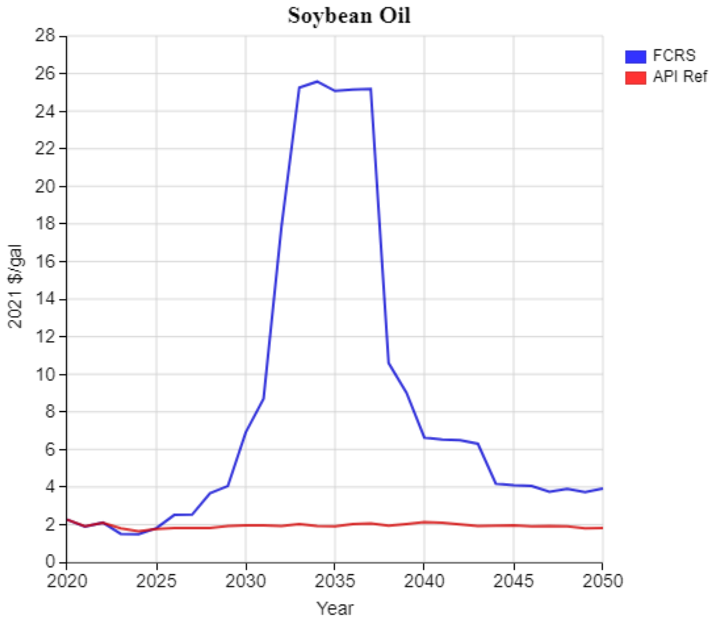


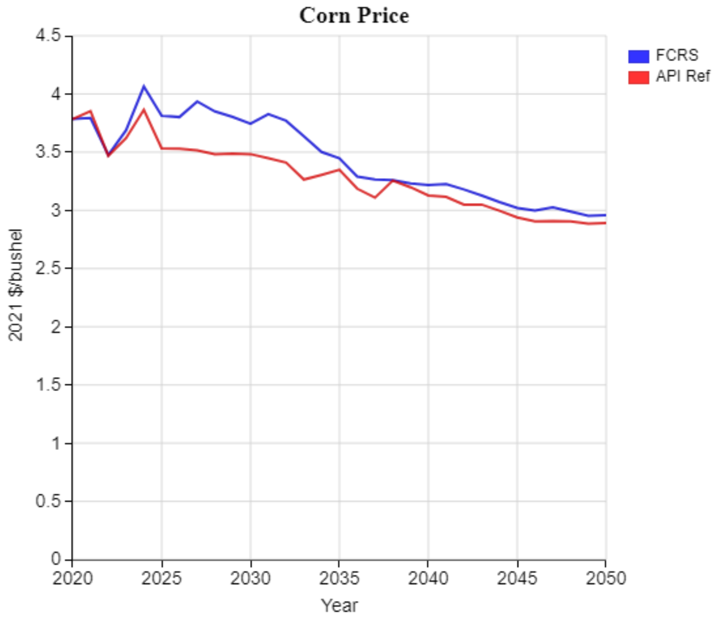



# Corn and Soybean Oil

- Soybean oil and white grease are represented through supply curves that expand modestly over time.
  - In the FCRS case, demand rises considerably for these feedstocks, and prices rise to over $25 per gallon for soybean oil and white grease rises to $3 per gallon (not shown). Once consumption drops, prices comes down but remain well above the reference case
  - These quantities are higher than experienced historically, so the upper end of the supply curves are highly uncertain
- Corn prices are just slightly higher than in the reference case and decline over time in both cases.

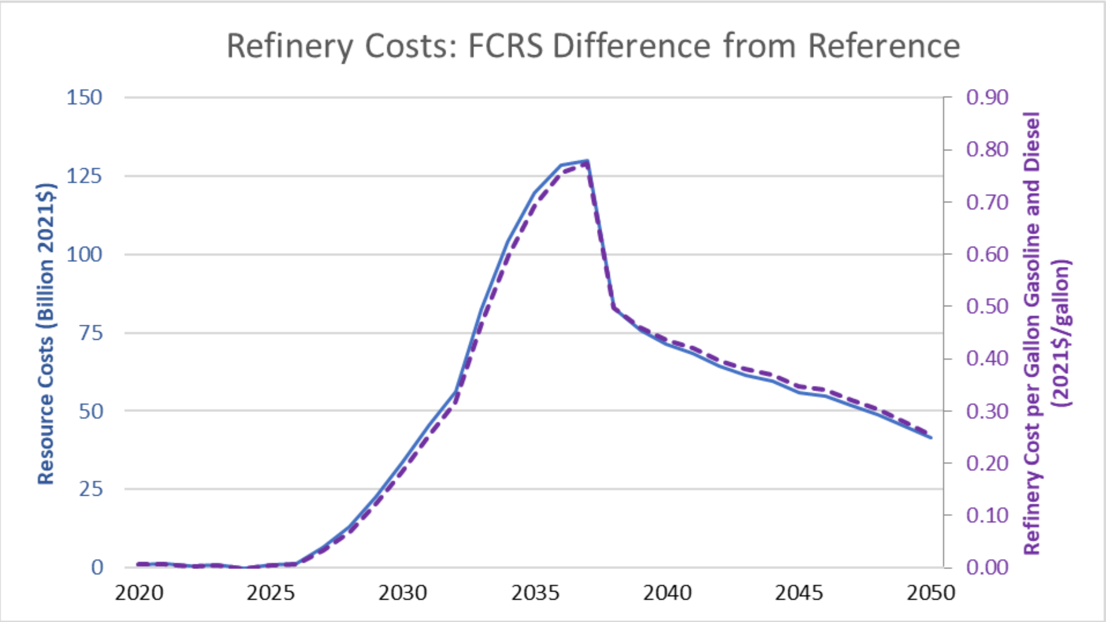


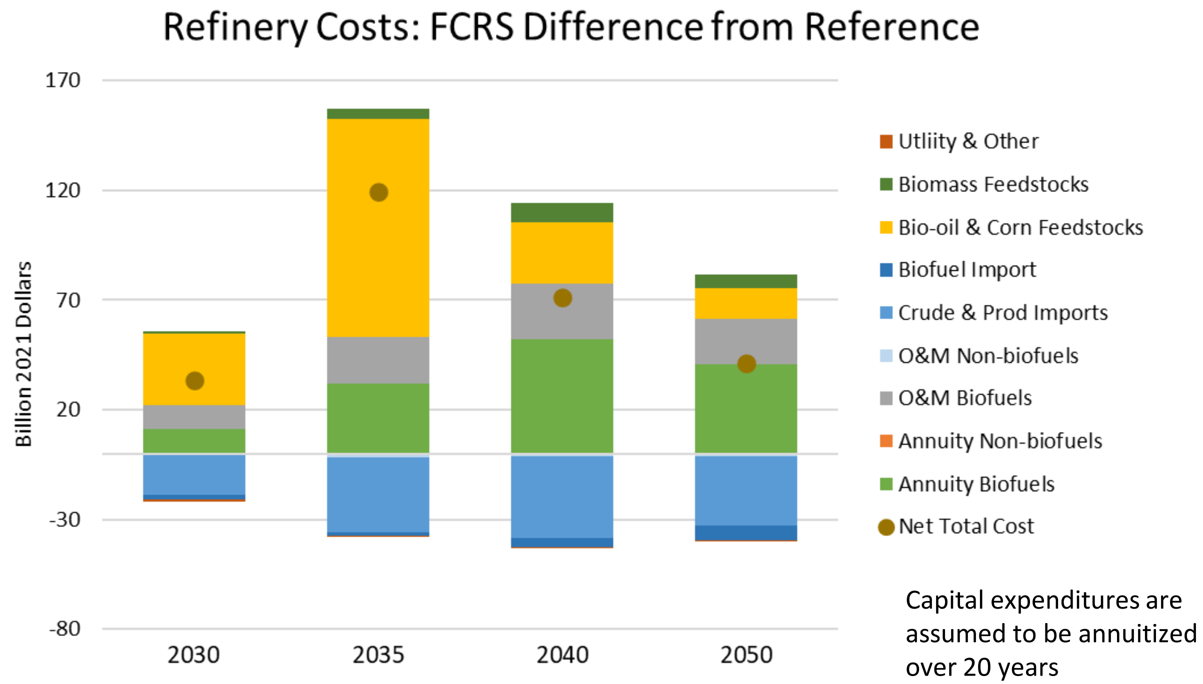



# Refinery Costs

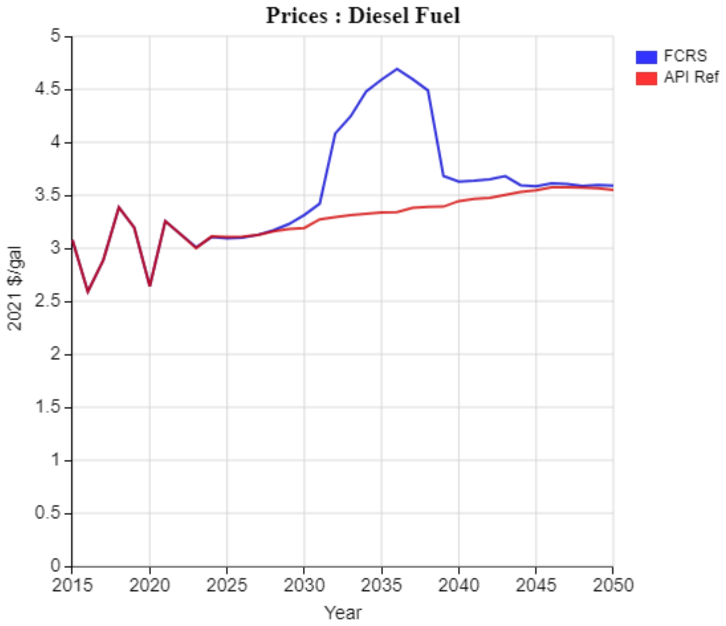
- Total costs to refineries (including biorefineries) increase in the FCRS case relative to the reference case by as much as $130 billion in 2037 which is equivalent to roughly $0.80 per gallon for gasoline and diesel (right axis of the lefthand chart).
  - The greatest portions of the increase are biofuel O&M and feedstock costs and capital annuities; these are offset partially by reduced crude oil and product import costs.

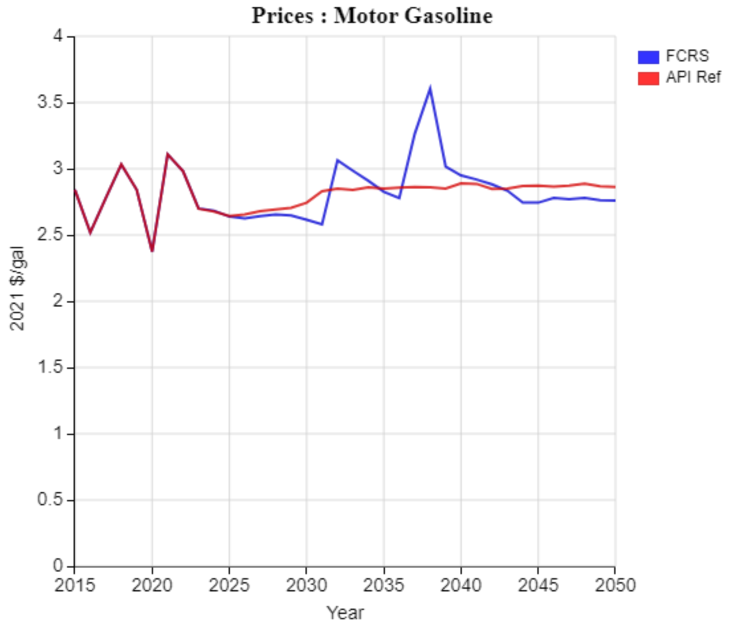


# Diesel and Gasoline Price Impact

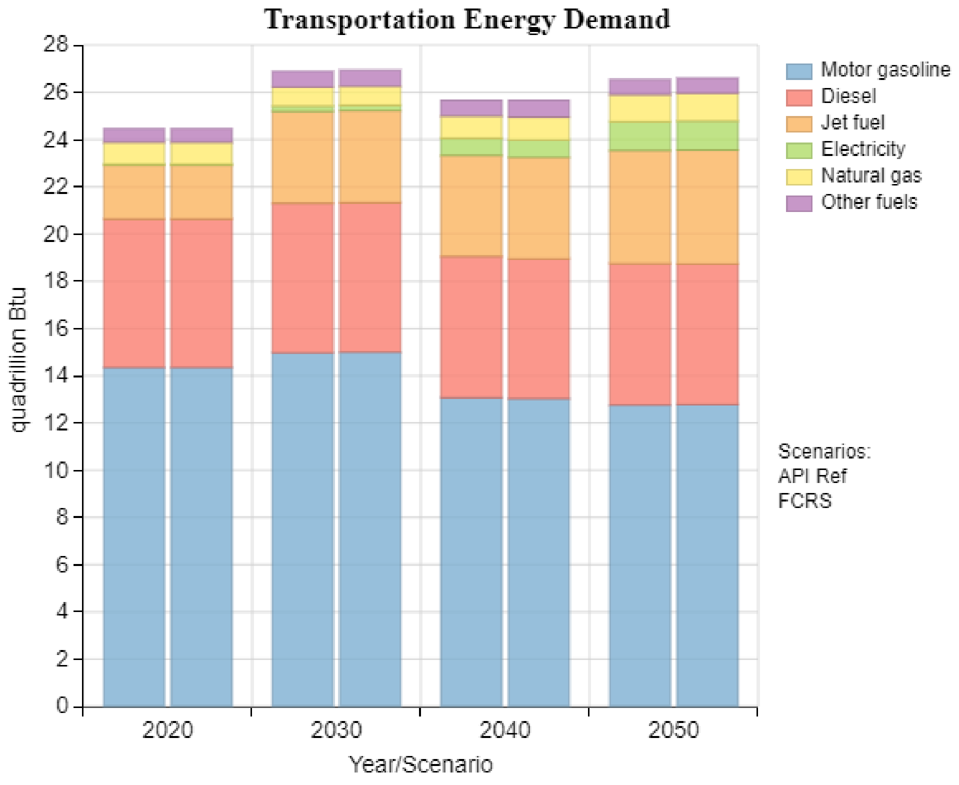
- Diesel and gasoline prices are generally higher due to the FCRS requirements, although prices return to the reference case prices in the long run.
  - Diesel prices mirror the FCRS price as the marginal sources of biofuels, such as renewable diesel, tend to be diesel replacements with high operating costs.
  - Gasoline prices also face downward pressure due to lower volumes produced and hence return to lower than reference case prices after 2045. This effect may be overstated because the model does not consider refinery capacity retirements.

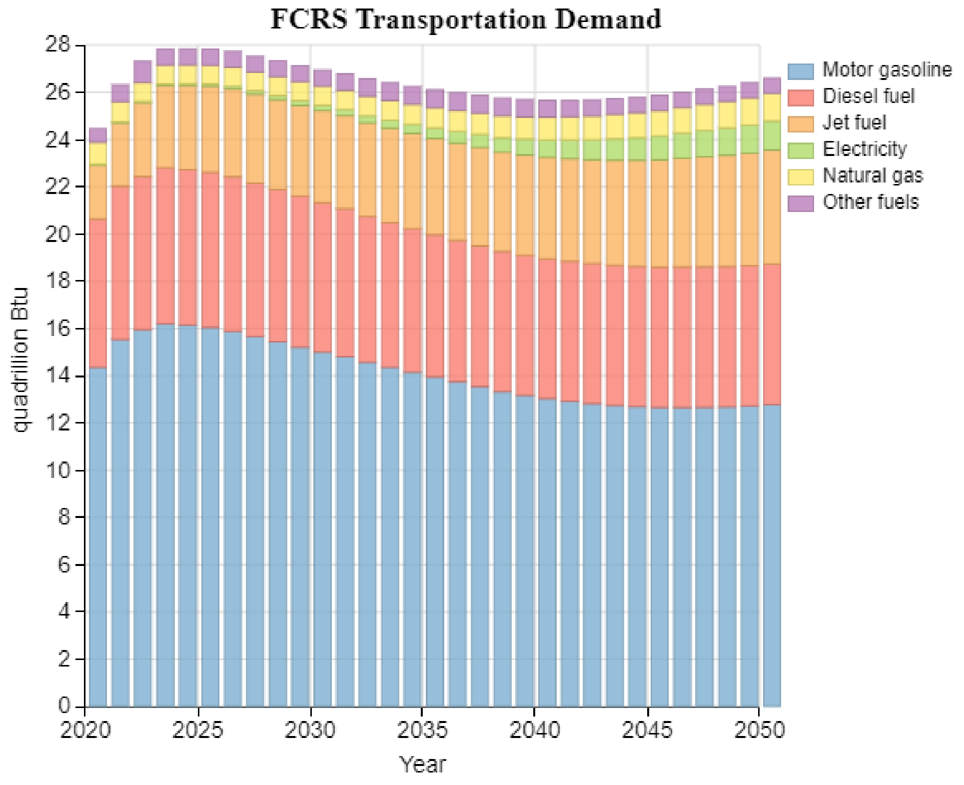


# Liquid Fuel Demands

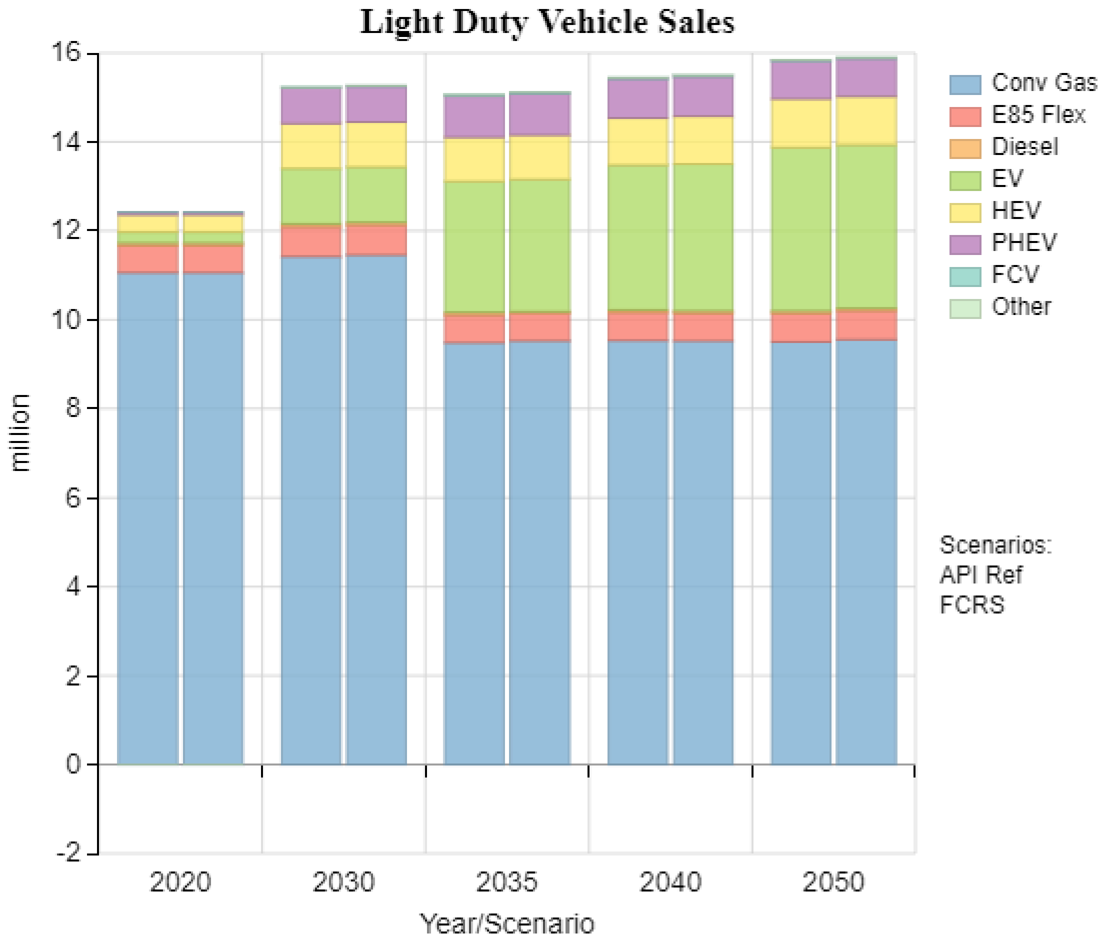
- Demand for liquid fuels remains relatively unchanged in the FCRS case relative to the reference case.
- In both cases, gasoline and diesel demand generally decline after 2023.



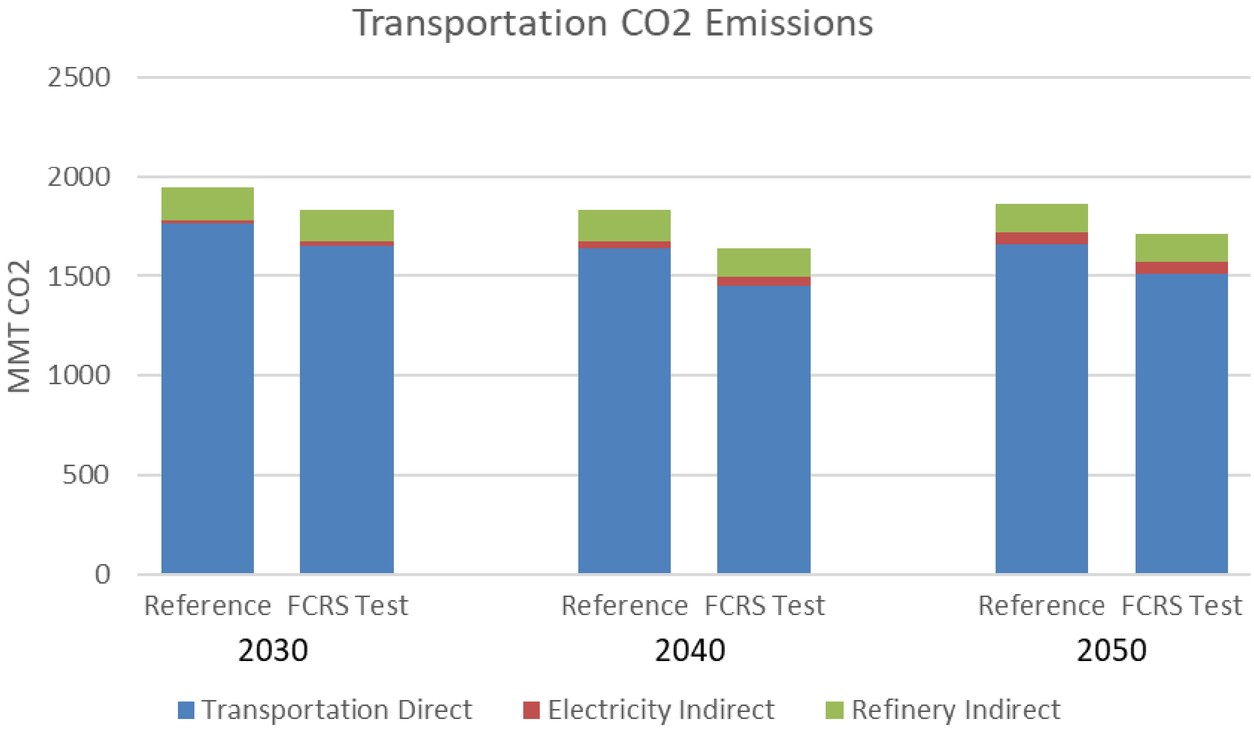
# Zero Emission Light Duty Vehicle Sales

- In the API22-NEMS cases, expanded state ZEV mandates result in more electric vehicles (EVs) and plug-in hybrid EVs (PHEVs) compared to the AEO 2022.
- The FCRS test case sales are impacted slightly by the increase in gasoline prices compared to the API Reference case
  - EV sales shares increase by 1.0% in 2035 and 1.4% in 2040.



# Transportation Energy-Related $CO_2$ Emissions – need to update

- The FCRS reduces total direct and indirect energy-related $CO_2$ emissions by 8% in 2050 compared to Reference case (excluding land impacts included in the carbon intensity scoring).
  - Refinery emissions are those associated with refining petroleum; the displacement of petroleum products with biofuels is counted as a direct emissions reduction.
  - There is little change in electricity emissions because the EV sales share is not impacted very much by the FCRS.



# Observations and Caveats

- A combined standard provides flexibility that allows diesel substitutes to play a larger role.
- The rate at which new biofuel capacity can be built affects the choice of biofuels used to meet the FCRS as well as the cost.
- Feedstock costs rise as demand increases and affect biofuel operating costs, although the degree of price increases is uncertain and depends on agricultural production responses to increased demand for biomass energy crops and soybeans.
  - There may be implications for food prices, although that is outside the boundary of this analysis.
- Once the FCRS requirement plateaus, declining gasoline and diesel demands lead to reduced demand for biofuels in future years.
- A combination of higher feedstock costs and less time to recover capital of new biofuel capacity drives up the FCRS credit price in the later years before the requirements peak in 2037.
- Banking of FCRS credits would likely smooth out credit prices and potentially retail prices as well.
- Projecting retail prices of gasoline and diesel is highly uncertain and depends on pricing mechanisms used for capital cost recovery across the fuels; gasoline prices shown here may be low because the model does not include refinery capacity retirements.
- In addition, the response in global markets to changes in U.S. petroleum and biofuel production and consumption may influence the relative costs of various compliance options as well as final product prices.

# Appendix: Additional Information

# Biofuels Available in API22-NEMS

**Table 9. Alternative fuel technology product type**

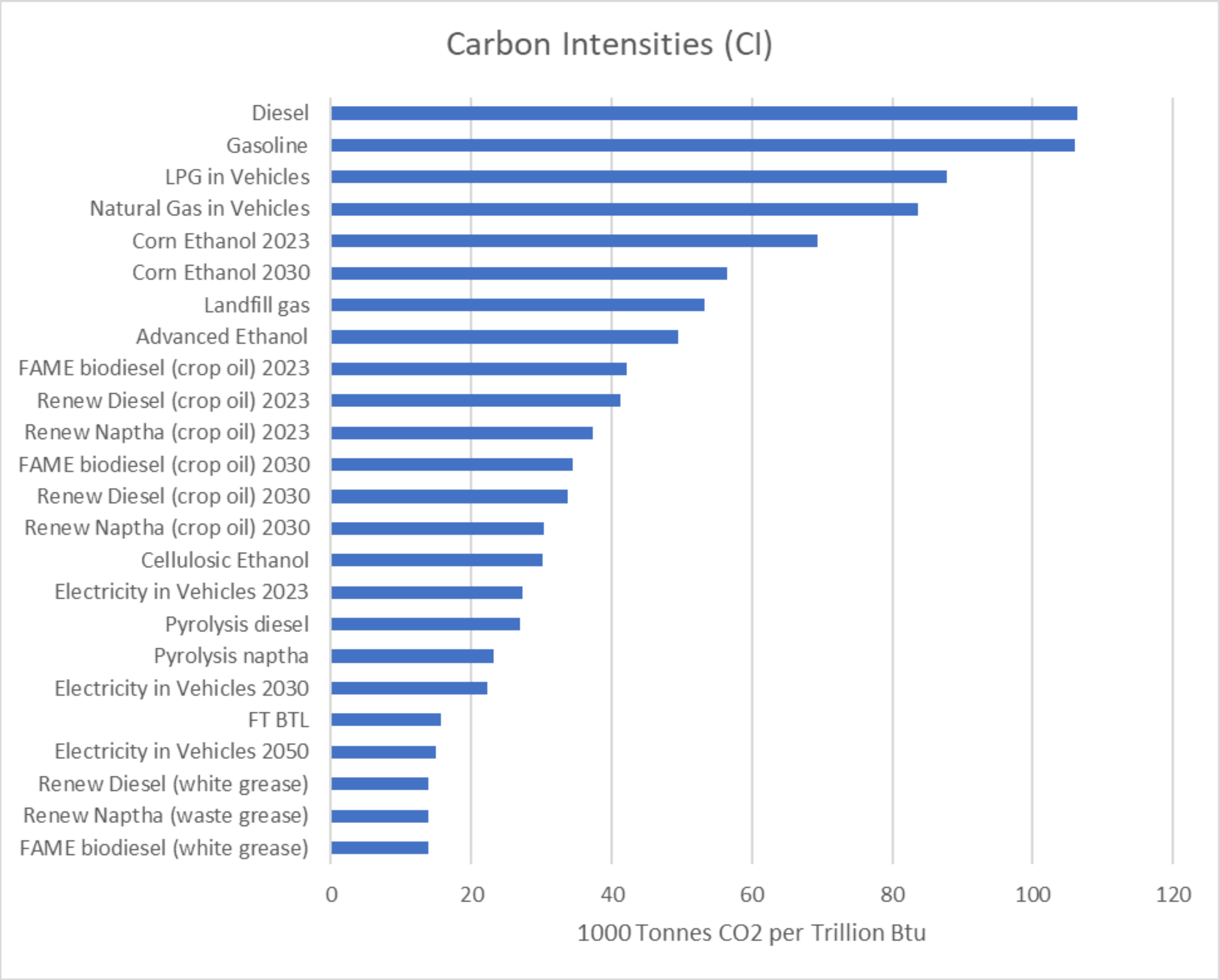
| Technology | Product type | Feedstock | Product yield (percentage by volume) |
|---|---|---|---|
| **Biochemical** | | | |
| Corn ethanol | Fuel grade | Corn | 100% ethanol |
| Advanced grain ethanol | Fuel grade | Grain | 100% ethanol |
| Cellulosic ethanol | Fuel grade | Stover | 100% ethanol |
| Biobutanol | Fuel grade | Corn | 100% biobutanol |
| **Thermochemical catalytic** | | | |
| Methyl ester biodiesel | Fuel grade | Yellow or white grease, or seed oil | 98.5% biodiesel<br>1.5% glycerol |
| Non-ester renewable diesel | Fuel grade | Yellow or white grease, or seed oil | 98% renewable diesel<br>2% renewable naphtha |
| Pyrolysis | Fuel grade | Agriculture residue, forest residue, or urban wood waste | 60% distillate<br>40% naphtha |
| **Thermochemical Fischer-Tropsch** | | | |
| Gas-to-liquids (GTL) | Fuel grade and refinery feed | Natural gas | 52% diesel<br>23% kerosene<br>24.5% naphtha<br>0.5% liquid petroleum gas (LPG) |
| Coal-to-liquids (CTL) | Fuel grade and refinery feed | Coal | 51% diesel<br>21% kerosene<br>28% naphtha |
| Biomass-to-liquids (BTL) | Fuel grade and refinery feed | Biomass | 22% diesel<br>46% kerosene<br>32% naphtha |

Source: U.S. Energy Information Administration, Office of Energy Analysis

Source: EIA, Assumptions to the Annual Energy Outlook 2022: Liquid Fuels Market Module

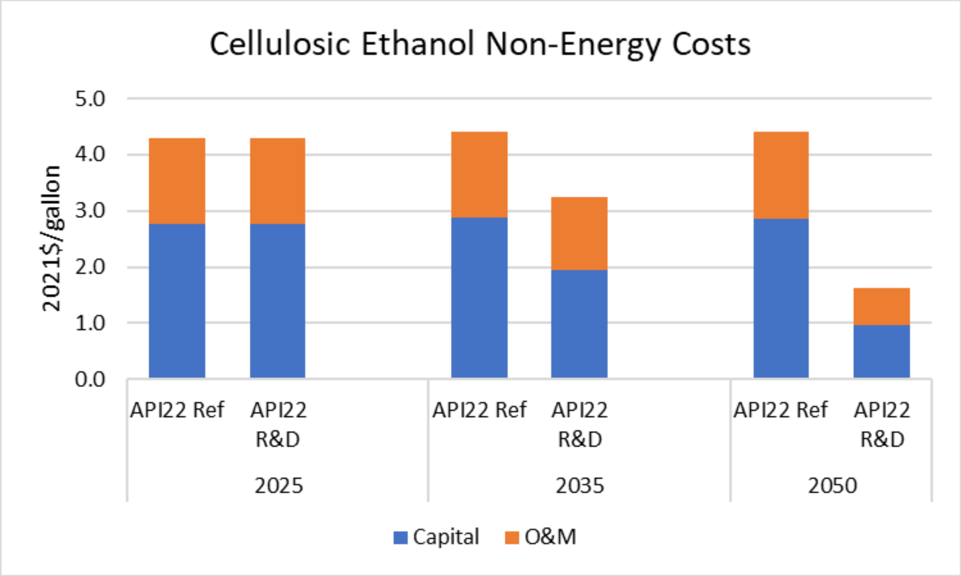
# Carbon Intensity Factors

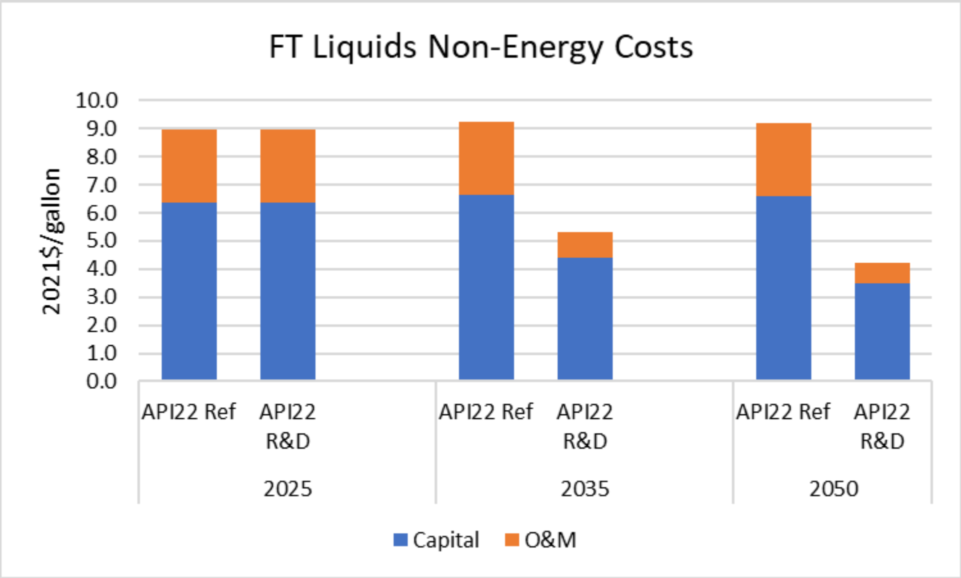
- Diesel and gasoline have the highest carbon intensities while Fischer-Tropsch BTL and biomass pyrolysis are among the lowest intensities
- Carbon intensity factors for corn ethanol and for biodiesel and renewable diesel using soybean oil are assumed to fall by 5% per year until 2027, based on assumptions provided by API.
- Electricity factors (including an EER of 3.4) are higher for the U.S. average than for California. The factors decline from 27 thousand tonnes $CO_2$ per trillion Btu to 15 by 2050.



# Biofuel R&D Costs Assumptions

- The AEO 2022 cellulosic ethanol and Fischer-Tropsch liquids production costs that we are using in the API22 reference and FCRS case are high relative to a recent IEA report.
- For the API22-NEMS $CO_2$ Price case, we assumed additional R&D would reduce these costs starting in 2030. FT liquids were also assumed to have an improved efficiency of 40% with no excess power production.




*Source: IEA, Advanced Biofuels – Potential for Cost Reduction, 2020. The Optimistic Potential Future case was used for cellulosic ethanol and the High case for FT liquids.*



*Note the difference in scales between the two charts.*