PIE ETE09
SAF Price computation

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March 2024

1 Calculation of the Total Cost of Fuel related to SAF Usage

1.1 Introduction and Preliminary Results

The objective is to define a cost function C^T that gives the total cost of fuel for a given airline based on the following parameters.

V, Fuel volume (L/year)
I, SAF incorporation rate [0,1]
A, Free allowances given in 2023 (tCO2)
Q, Carbon quota allocated by the EU [0,1]
P_{C0_2}, Carbon ton price (USD/L)
P_{SAF}, SAF price (USD/L)
P_k, Kerosene price (USD/L
R, Allowance for reducing SAF-related surcharge [0,1]

There is a bijection directly linking CO2 emissions and the volume of consumed fuel :

$$V = E_{CO_2} \frac{1000000}{E_k^V LCA_k} \tag{1}$$

where E_{CO_2} is the CO2 emissions in tons, E_k^V is the volumetric energy of kerosene in MJ/L, and LCA_k is the Life Cycle Assessment factor in gCO2eq./MJ. For simplicity, let's denote :

$$\alpha = \frac{E_k^V LCA_k}{1000000} \tag{2}$$

1.2 Case without SAF Usage

The total cost of kerosene C_k^T consists of the raw material cost C_k^{MP} and the carbon cost $C_k^{CO_2}$. Thus :

$$\begin{aligned} C_{k,0}^T &= C_{k,0}^{MP} + C_{k,0}^{CO_2} \\ &= V.P_k + (E_{CO_2} - A.Q).P_{C0_2} \\ &= V.P_k + (\alpha.V - A.Q).P_{C0_2} \end{aligned}$$

The cost function can be written as :

$$C_{k,0}^T(V, A, Q, P_{C0_2}, P_k) = V.P_k + (\alpha.V - A.Q).P_{C0_2} \tag{3}$$

1.3 Case with SAF Usage

The fuel volume V can be divided into kerosene volume V_k and SAF volume V_{SAF}.

$$V = V_k + V_{SAF} \tag{4}$$

The proportion of SAF and kerosene is defined by the incorporation rate I :

$$\begin{aligned} V_{SAF} &= V.I \\ V_k &= V.(1-I) \end{aligned}$$

The total cost C^T is then composed of the kerosene cost C_k^T, the SAF cost C_{SAF}^T, and the allowance for reducing the SAF-related surcharge granted by the EU R_{UE} :

$$C^T = C_k^T + C_{SAF}^T + R_{UE} \tag{5}$$

The total cost of kerosene C_k^T is as previously composed of the raw material cost C_k^{MP} and the carbon cost $C_k^{CO_2}$:

$$C_k^T = V_k.P_k + (\alpha.V_k - A.Q).P_{C0_2} \tag{6}$$

For SAF, we neglect the carbon cost of SAF initially. So :

$$C_{SAF}^T = V_{SAF}.P_{SAF} = C_{SAF}^{MP} \tag{7}$$

The free allowance granted by the EU to cover the surcharge related to SAF R_{UE} depends on the proportion R of the surcharge $(C_k^{MP} + C_{SAF}^{MP}) - C_{k,0}^{MP}$ covered by the allowance, where $C_{k,0}^{MP}$ is the raw material cost in the case of no SAF usage :

$$R_{UE} = -R.((C_k^{MP} + C_{SAF}^{MP}) - C_{k,0}^{MP}) \tag{8}$$

Thus :

$$\begin{aligned} C^T &= C_k^T + C_{SAF}^T + R_{UE} \\ &= C_k^T + C_{SAF}^T - R.(C_k^{MP} + C_{SAF}^{MP} - C_{k,0}^{MP}) \\ &= C_k^{MP} + C_k^{CO_2} + C_{SAF}^{MP} - R.(C_k^{MP} + C_{SAF}^{MP} - C_{k,0}^{MP}) \\ &= (1-R).(C_k^{MP} + C_{SAF}^{MP}) + R.C_{k,0}^{MP} + C_k^{CO_2} \\ &= (1-R).\left(V_k.P_k + V_{SAF}.P_{SAF}\right) + R.V.P_k + (\alpha.V_k - A.Q).P_{C0_2} \\ &= (1-R).\left(V.(1-I).P_k + V.I.P_{SAF}\right) + R.V.P_k + (\alpha.V.(1-I) - A.Q).P_{C0_2} \end{aligned}$$

Therefore :

$$\begin{aligned} C^T(V, I, A, Q, P_{CO_2}, P_{SAF}, P_k, R) = &(1-R).\Big[V.(1-I).P_k + V.I.P_{SAF}\Big] \\ &+ R.V.P_k + \Big[\alpha.V.(1-I) - A.Q\Big].P_{C0_2} \end{aligned}$$

2 Encouragement for SAF Usage

The goal is to determine if it is interesting for an airline to incorporate SAF into its fuel mix. We first study the influence of the incorporation rate.

2.1 Influence of the Incorporation Rate

It is observed that the cost function C^T is linear in I :

$$\begin{aligned}\frac{\partial C^T}{\partial I} &= V.(1-R)(-P_k + P_{SAF}) - \alpha.P_{CO_2}.V \\ &= V.\left[(1-R).(P_{SAF} - P_k) - \alpha.P_{CO_2}\right]\end{aligned}$$

$\frac{\partial C^T}{\partial I}$ is a constant with respect to I. This allows us to analyze the determinants of the incentive to purchase SAF. For an airline to be financially encouraged to incorporate SAF into its fuel mix, it is necessary that $\frac{\partial C^T}{\partial I} < 0$. It is observed that the carbon ton price P_{CO_2} must be sufficient to offset the price difference $P_{SAF} - P_k$ between SAF and kerosene. The condition can be explicitly stated as :

$$P_{CO_2} > \frac{1-R}{\alpha}.(P_{SAF} - P_k) \tag{9}$$

When this condition is met, it is financially beneficial for an airline to incorporate SAF. Moreover, there is no optimal mix, but the more SAF is used, the more cost savings are achieved.

Numerical application :

$$\begin{aligned}R &= 0,7 \\ \alpha &= \frac{E_k^V LCA_k}{1000000} = 3,10.10^{-3}\ \text{tCO}_2.\text{L}^{-1} \\ P_{CO_2} &\approx 96,7.(P_{SAF} - P_k)\ \text{USD/tCO}_2\end{aligned}$$