Supplementary Material

1.1 Calculations for the choice of steel mill gas source

Gas that would otherwise have been flared ($F_i(t)$) is used firstly to meet the demand (D_i) as much as possible. It may be the case that enough gas is being flared to meet the full demand. If this is not the case, then the remaining demand ($S^1{}_i(t)$) can be calculated as follows:

$$S^1{}_i(t) = \max\left(D_i - F_i(t); 0\right) \quad in\ [\frac{Nm^3}{h}]$$

As much of the remaining demand ($S^1{}_i(t)$) as possible is taken from gas that would have otherwise been used for power generation. First, the power generated ($P^2{}_i$) from a stream of steel mill gas (V_i) is calculated as follows, followed by the replacement cost of the gas ($RC^P{}_i(t)$) when its electricity production is replaced with natural gas or electricity.

$$P_i^{electricity} = \frac{LHV_i \cdot \eta_{Power\ plant} \cdot V_i}{3600} \ in\ [MW]$$

$$RC_{i,h}^{electricity}(t) = \min\left(\frac{\pi_{NG}(t) \cdot P_i^{electricity}}{\eta_{power\ plant}}; \pi_{electricity}(t) \cdot P^2{}_i\right) \ in\ [\frac{€}{h}]$$

The replacement cost per tonne is then calculated, where ρ_i is the density of the gas.

$$RC_i^{electricity}(t) = \frac{RC_{i,h}^{electricity}(t)}{V_i \cdot \rho_i / 1000} in\ [\frac{€}{t}]$$

Finally, the demand cannot be met by gas that would have otherwise been used for electricity generation ($E_i(t)$) must be determined. This amount ($S^2{}_i(t)$) is calculated as shown below.

$$S^2{}_i(t) = \max\left(S^1{}_i(t) - PP_i(t); 0\right) \quad in\ [\frac{Nm^3}{h}]$$

Any remaining demand ($S^2{}_i(t)$) must be met by gas that would otherwise have been used for heating. The power required to replace this gas ($P^3{}_i$) is first calculated before the replacement cost is determined:

$$P^{\text{heating}}{}_i(t) = \frac{LHV_i \cdot \eta_{burner} \cdot V_i(t)}{3600} \quad in\ [MW]$$

$$RC_{i,h}^{heating}(t) = \frac{P^3{}_i(t) \cdot \pi_{NG}(t)}{\eta_{burner}} \quad in\ [\frac{€}{h}]$$

$$RC_i^{heating}(t) = \frac{RC_{i,h}^{heating}(t)}{V_i \cdot \rho_i / 1000} \; in \; [\frac{€}{t}]$$

Lastly, the total replacement cost is calculated by simply summing the replacement costs calculated above.

$$RC_{\mathrm{T}}(\mathrm{t}) = \frac{S^1{}_i(t)}{D_i} \cdot RC^{\mathrm{electricty}}{}_i(t) + \frac{S^2{}_i(t)}{D_i} \cdot RC^{\mathrm{heating}}{}_i(t) \quad in \;\; [\frac{€}{tonne}]$$

1.2 Evaluation of the base scenario

Over the course of a year, the replacement cost (Figure 11 in the paper) is erratic and does not follow clear trends. This is largely due to the influence of the flare gas. At the times when the replacement cost is zero, there is enough BFG being flared to meet the 100 kt demand for the chemical plant. Consequently, during the peaks, there is no or very little flare gas available. Although there are also circumstances where the replacement cost is under five but not zero, signifying that there is some BFG being flared but not enough to meet the complete demand, these instances are rare for a 100 kt demand. This is because when gas is being flared, it is usually in large amounts but for a short time. In particular, for BFG, which has a total flow of around 8000 kt/a (~700,000 Nm^3/h), the amount when flared will usually be larger than required for a 100 kt/a demand (~9000 Nm^3/h). It is not possible to predict when gas will be flared; it is considered random in both timing and amount, although the frequency and amount vary with different steel mills. This is reflected when the frequency of different economic values is studied, as shown in Figure 1. The vast majority of the curve seems to follow roughly a normal distribution, with slightly more occurrences on the 'left' or lower value side. It can be inferred that this is caused by the relatively normal distribution of electricity grid prices over the year, with it being slightly stacked to the left as there will be occurrences when gas has been flared, but not enough to meet complete feedstock demands. The large frequency with a value of zero signifies the occurrences where enough gas is flared to meet the entire feedstock demands, *i.e.* the gas is effectively free. 20.4% of BFG was used as flare gas. The gas had a value of zero 9.67% of the time (Figure 1); this shows that more than half the time gas was flared, it was enough to meet complete feedstock demands.

The shape of the distribution for Germany is notably thinner and taller than for France; this is due to more consistent electricity prices, leading to a higher occurrence of times steel mill gas had the same value. This is also visible in **Error! Reference source not found.**, with the distribution for Germany having a lower variance than France. There are also slightly more occurrences of zero-valued gas in Germany, which can be explained by the higher usage of renewable electricity production, leading to times when the grid electricity was effectively free.

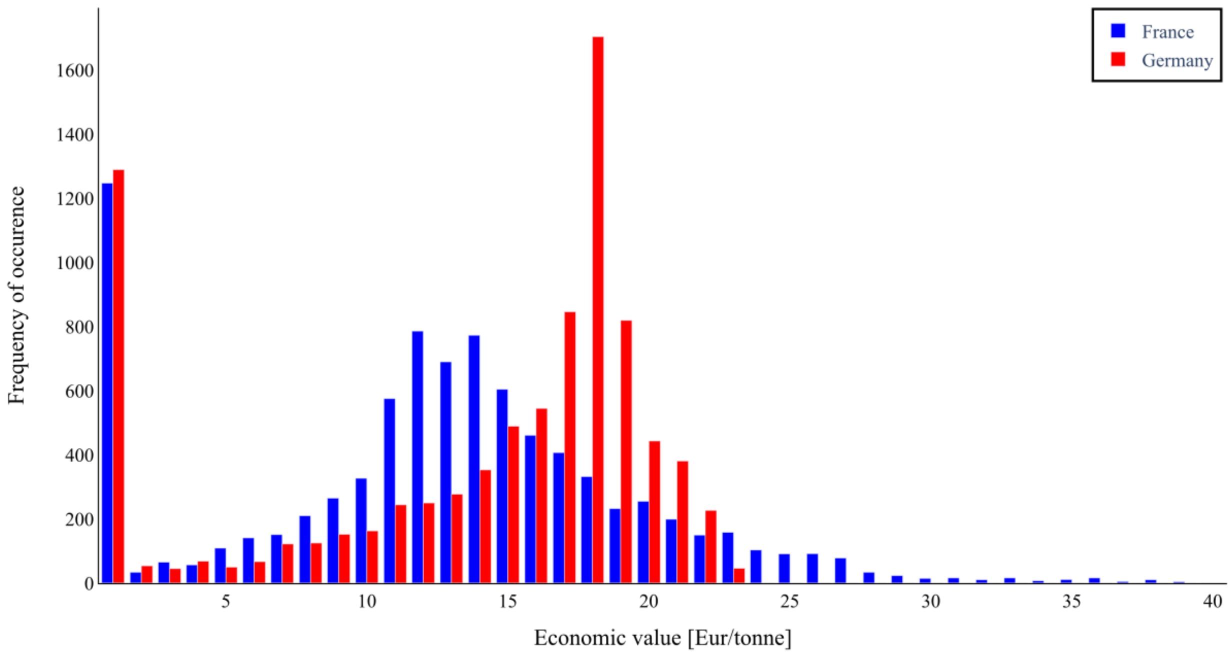

Figure 1: The number of occurrences of each one euro price interval when sorting the 8,760 hourly prices for steel mill gas

As a chemical company would have a steady supply of steel mill gas as feedstock, the average replacement costs over longer periods such as months or years are most relevant. Due to its cheaper grid electricity, it is 8.1% cheaper to buy BFG in France than in Germany for the baseline scenario. However, it is important to note that both prices are comparatively low. It can therefore be concluded that for the baseline scenario, the choice to build a chemical plant utilizing steel mill gas as feedstock in either Germany or France does not strongly depend on the economic value of the steel mill gas.

1.3 Results for differing flare rate scenarios

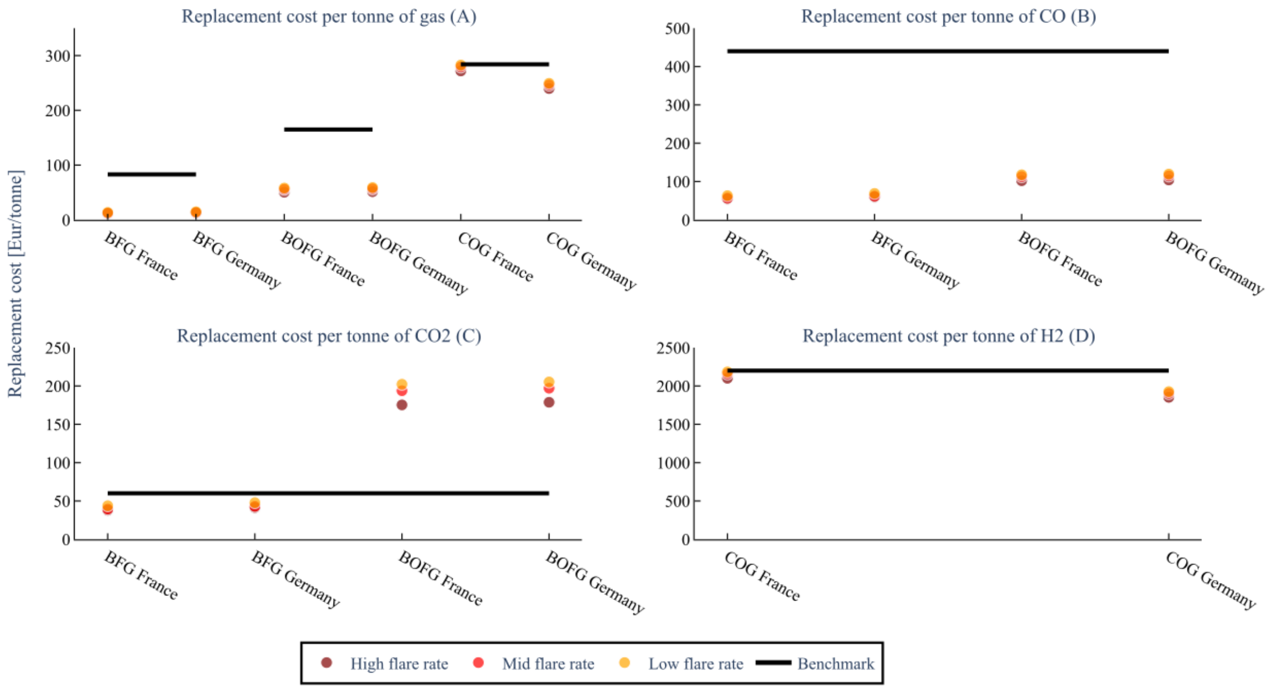

Figure 2: The replacement cost of the steel mill gas for the three flaring scenarios; low flare rate (0.5 vol%), mid flare rate (2 vol%), and high flare rate (5 vol%) for a capacity of 100 kt/a

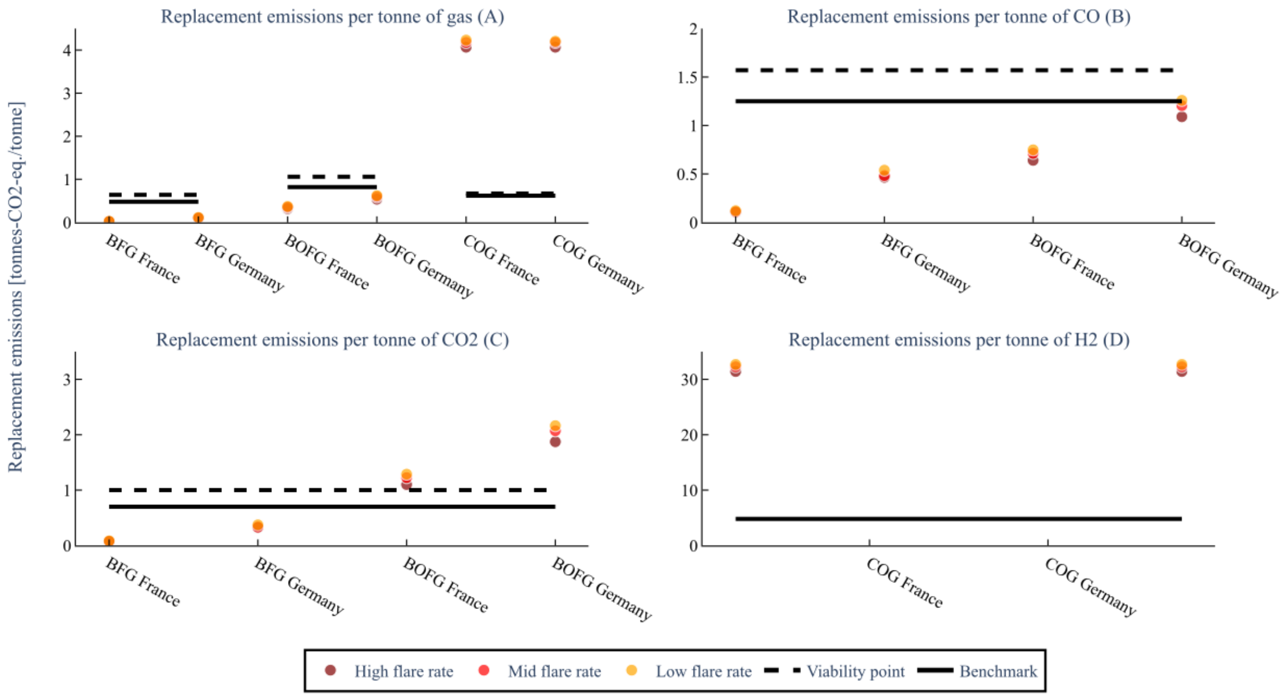

Figure 3: The GHG emissions required to replace the energy provided to the steel mill by the steel mill gas for the three flaring scenarios; low flare rate (0.5 vol%), mid flare rate (2 vol%) and high flare rate (5 vol%) for a capacity of 100 kt/a

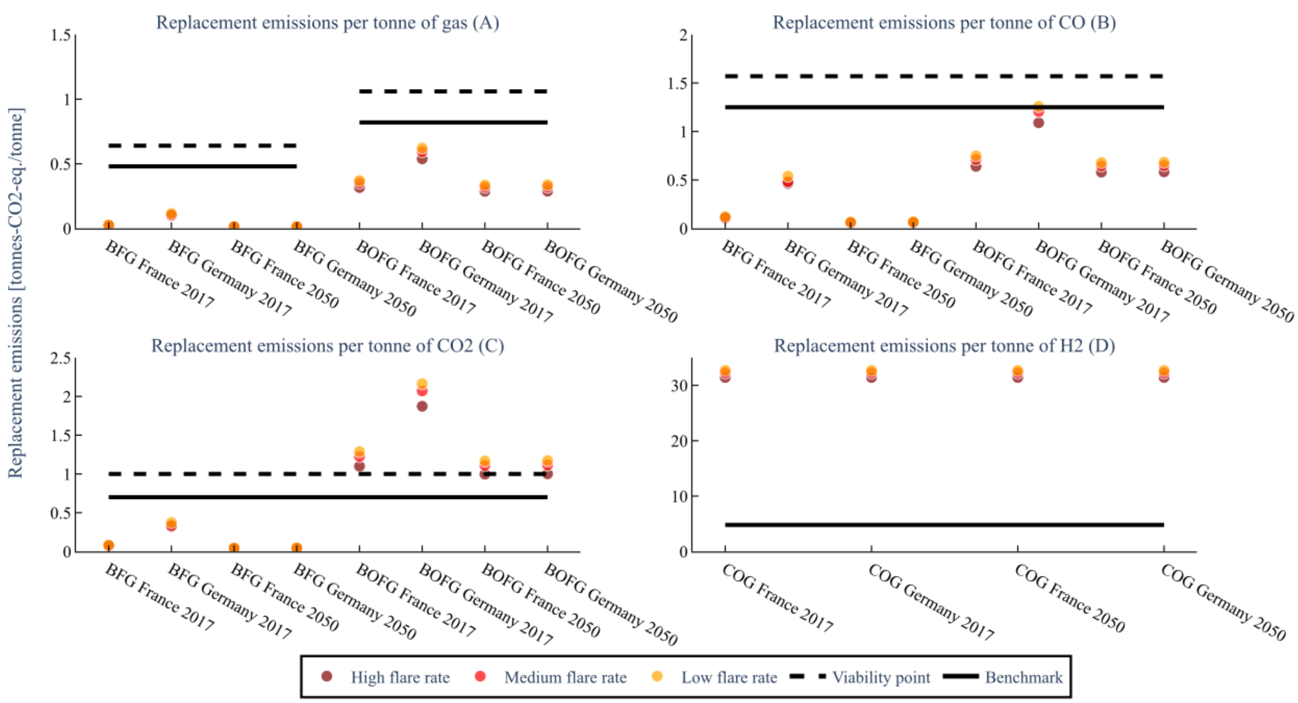

Figure 4: The GHG emissions required to replace the energy provided to the steel mill by the steel mill gas for the three flaring scenarios in the year 2050; low flare rate (0.5 vol%), mid flare rate (2 vol%), and high flare rate (5 vol%) for a capacity of 100 kt/a