Cost Benefit Analysis of Hydrogen for Energy Transition in Container Glass Sector: A Case Study

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Overview

Although a crucial source of global prosperity, the industrial sector was responsible for roughly 24% of global greenhouse-gas (GHG) emissions in 2018 (McKinsey&Company, 2018). Within the Paris Agreement of 2015, governments have set ambitious targets for reducing GHG emissions in the sector. This study examines the viability of a pilot project for decarbonizing the container glass industry in France. Hydrogen is viewed as a promising energy vector to achieve sector's carbon-neutrality due to its compatibility with the current fossil fuel-fired furnaces on large scale, the supplementary values of ancillary services, and the co-production of oxygen and heat. Nevertheless, implementing green hydrogen through electrolysis is challenging given the need for continuous energy supply in furnaces, which excludes the direct use of intermittent renewable energy sources and leaves the sector dependent on grid electricity (BloombergNEF, 2021). Dependence on grid electricity poses the risk of volatile electricity market prices affecting energy supplier decision-making. Another factor impacting the hydrogen trade is the readiness of industries to switch from their polluting technologies which is a function of fossil fuels and carbon market prices as the most significant parameters. Historically, the European electricity, gas, and carbon (EU ETS) market prices have fluctuated over time, posing high level of uncertainties for private actors to invest in first-of-a-kind decarbonization projects. In this study, we analyze the viability of deploying hydrogen in a the case of container glass industry from both public and private perspectives. We address the issue of uncertain market prices and assess different support mechanisms to mitigate these risks for the economic viability of the hydrogen deployment in industrial applications.

Methods

This paper defines a cost-benefit analysis (CBA) framework to estimate the economic efficiency of replacing natural gas by hydrogen in a container glass manufacturing plant. In this CBA, not only the economic effects for the private decision makers but also the environmental externalities that impact the social decision-making are included. For a social planner, the costs include capital investment costs of electrolyzer and converting the industrial equipment and site (CAPEX), as well as the operational and maintenance cost, and the cost of electricity supplied to the electrolyzer (OPEX). On the benefit side, there are savings on natural gas consumption, revenue from oxygen co-production, and avoiding the damage cost of CO_2 and local pollutions (NOx, SOx, and CO) according to the Environmental Prices Handbook (Bruyn, 2018). The project is socially beneficial whenever the abatement cost of replacing the polluting technology is less than the social cost of carbon (SCC):

$$\text{Abatement Cost}\left[\frac{€}{tCO_2}\right]=\frac{\text{CAPEX+OPEX - Savings On NG - Benefits from Oxygen - Local Pollution Abatement}}{\text{Total Abatement of } CO_2}\leq \text{SCC} \quad (1)$$

From private perspective, two parameters can impact the hydrogen trade: the levelized cost of hydrogen production ($LCOH_2$) for the energy supplier and the willingness to pay (WTP) of industry switching to hydrogen from a counterfactual reference case when it consumes NG and pays for CO_2 emissions on EU ETS market. To be tradable, the contractual hydrogen price should be more than the minimum $LCOH_2$ and less than maximum industry's WTP:

$$LCOH_2 \leq H_2 \text{ Contractual Price} \leq \text{WTP} \quad (2)$$

$$LCOH_2\left[\frac{€}{kg}\right]=\frac{\text{Capital Cost of Electrolyzer+Operational and Maintenance Cost +Electricty Costs - Benefits from Oxygen}}{\text{Total Amount of Hydrogen Production}} \quad (3)$$

$$\text{WTP}\left[\frac{€}{kg}\right]=\frac{\text{Savings on NG+Savings on } CO_2 \text{ - Capital Cost of Converting the Industrial Equipment and Site}}{\text{Total Amount of Hydrogen Demand}} \quad (4)$$

Results

Considering NG price of 50€/MWh, EU ETS carbon price of 60€/tCO_2, and electricity price of 60€/MWh as the base input prices, the abatement cost of the project is found at 115€/tCO_2. This value is lower than the social cost of carbon reported by Quinet (Quinet, 2019) for the French Strategy (136€/tCO_2 at the launching year of the pilot project) indicating the social benefits of investing on the project. From a private standpoint, the levelized hydrogen production cost for the energy supplier is 4.88 €/kg with an elasticity of 0.99 to the electricity price (i.e. 1% increase in market electricity price would increase the $LCOH_2$ by 0.99%). On the other hand, the willingness to pay of industry is not more than 2.13 €/kg with elasticity of 0.94 to NG price and 0.20 to CO_2 price. A higher production cost compared to industry's willingness to pay for hydrogen obstacles the trade among the two private actors in a absence of any supporting instruments.

The results on the Table 1 show that with the assumed base NG price of 50€/MWh and electricity price of 60€/MWh, the project is socially viable with total positive profits of 48M€, however, not profitable from private satnd point with total negative profits of -112 M€. As illustrated in the table, the gap between social and private analysis comes from three main factors (i) lower risk and therefore a lower discount rate imposed on public entities due to their higher willingness to accept and manage the risks compared to the private firms, (ii) social benefits of abatement of local pollutions, and (iii) discrepancy between social cost of carbon and carbon market prices on EU ETS. During its 15-year history, the EU ETS carbon price has fluctuated between 0€/tCO_2 and ~60€/tCO_2. Industrial companies and financial lenders therefore perceive the ETS carbon price as an insufficiently reliable basis for final investment decisions. One support mechanism to mitigate the risk of uncertain EU ETS prices is Carbon Contract for Differences (CCfDs) to pay the industry the difference between the EU ETS and a contractual carbon price. The mitigation of the risks can be incorporated by dedicating smaller discount rates on the private parties. Table 1 also shows the results of the private CBA in the presence of CCfD with higher benefits through savings on CO_2 emissions. Nevertheless, considering the base input prices, in order to achieve the break-even point of the project for the private investors, the required contractual carbon price should be at least 360€/tCO_2 (i.e. the government should pay the industry 300€/tCO2 as the difference of the contractual carbon price of 360€/tCO_2 and EU ETS price of 60€/tCO2). In addition, CCfD alone does not mitigate the uncertainty of gas and electricity market prices. This fact highlights the need for other complementary support mechanisms.

Table 1. The Cost-Benefit Analysis Results from Social and Private Perspectives

	Costs			**Benefits**				**Total Discounted Profits (Benefits-Costs) (M€)**
Perspective	**CAPEX* (M€)**	**OPEX* (M€)**	**Electricity Cost* (M€)**	**Savings on NG* (M€)**	**Savings on CO_2* (M€)**	**Benefits from O_2 Production* (M€)**	**Benefits of the Local Pollution Abatement* (M€)**	
Social (2% DR**)	-48	-18	-401	+181	+100 (with SCC=136€/tCO_2)	+51	+183	**+48**
Private (12% DR**)	-48	-8	-180	+81	+20 (with carbon market price=60€/tCO_2)	+23	Not Applied	**-112**
Private with CCfD (7% DR**)	-48	-12	-257	+117	+70 (with low contractual carbon price=150€/tCO_2) +168 (with high contractual carbon price=360€/tCO_2)	+32	Not Applied	**-98** (with low contractual carbon price=150€/tCO_2) **0** (with high contractual carbon price=360€/tCO_2)

*total discounted values over the 20 years of the project lifetime

**Discount Rate

Conclusions

The production of industrial materials, such as container glass, is a continuous process requiring a constant supply of energy fuels that poses the risk of uncertain and unfavorable market prices. The support mechanisms should provide revenue support to overcome the cost challenge of trading low-carbon hydrogen against cheaper higher-carbon counterfactual fuels and mitigate the risk of market prices uncertainties. For the case study of container glass industry, we compare two approaches: supply-side and the demand-side revenue support mechanisms. In the demand-side, the social planner could support industry investing in hydrogen through a Carbon Contract for Difference (CCfD) to pay the difference between a set strike price and CO_2 market price. In the supply side, the energy supplier could be paid a premium price for every unit of hydrogen produced. This premium price is either a fixed price paid in addition to the industry's WTP, or a siliding (variable) premium price that covers the difference between the industry's WTP and the $LCOH_2$. Flat subsidies could be also other forms of supporting instruments. The benefits of each different mechanism are discussed in this study to accelerate the deployment of hydrogen for industrial applications.

References

BloombergNEF. (2021). *Hydrogen: Stable Production from Renewables and Grid.*
Bruyn, e. a. (2018). *Environmental Prices Handbook.* Delft: CE Delft.
McKinsey&Company. (2018). *Decarbonization of industrial sectors: the next frontier.*
Quinet, A. (2019). *La valeur de l'action pour le climat.*