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Price Dynamics of Carbon Dioxide, Electricity, and Natural Gas with Respect to Power to Gas Technologies

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Abstract

The present study investigated the price dynamics of carbon dioxide, electricity, natural gas, and capital interest rates to generate a series of cost curves for designing power to gas energy storage systems in different locations. The profitability of power to gas energy storage systems is driven by commodity and regulatory markets that control energy, greenhouse gas, and labour prices. The ability to rapidly determine the feasibility of this technology in different locations requires a rigorous sensitivity analysis of these four parameters in order to determine the net cost or profit of any installation. An iterative calculation approach was utilized to generate profitability curves for a variety of different applications and locations. The analysis was based on CO2Storage Ltd's power-to-gas technology that converts combustion exhaust emissions into renewable methane. This approach yields a profitable path for converting all existing combustion systems into renewable based energy storage systems.

Introduction: The increasing use of intermittent renewable power across the world is leading to increasing strain on management of electric power generation in response to power demand. Renewable power generation cannot be relied upon at all times. One solution to the problem of intermittency is the employment of energy storage technologies.

CO2 Storage is a PtG technology that provides storage of renewable energy. The technology can be retrofitted to combustion generators. It captures the CO2 emissions and transfers the gas to storage. The CO2 is converted into methane fuel via reaction with hydrogen from electrolysis. The electrolysis must be carried out when the cost of electricity is low enough. The methane fuel can then be resupplied to the generator when power is required from the system.

The business model of any PtG system relies on the costs of natural gas, CO2 and electricity. When modelling the revenues that can be made from such operations, it is valuable to understand which factors are the most impactful and which can be treated with less attention.

This analysis attempts to determine the relative level of influence that the prices of each of the three commodities has on the financial returns from operation. Livolt Ltd is developing scalable PtG system for deployment in diverse environments:

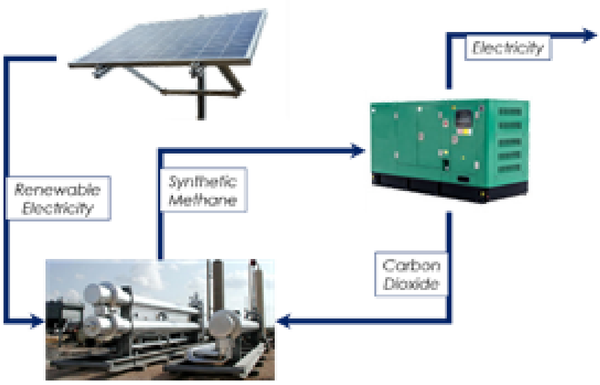

Figure 1: Power to Gas System Schematic

Method: A cost-sensitivity analysis was performed for the principle of a power-to-gas (PtG) technology that consumes electricity whilst producing natural gas along with CO2 emissions abatement. Microsoft Excel was used to carry out a cost-sensitivity analysis. Arrays of random instances of the variable prices of natural gas, electricity and CO2 emissions in Indian markets were created and the net revenues of the operation when carried out were correlated graphically with each of these prices separately. The influence of each of the three commodities' prices was measured and compared. It was found that the cost of electricity decidedly overwhelmed the effect of changes in the other prices on the revenues produced by a P2G system.

Data Preparation:

The prices of solar power (ETEnergyWorld, 2019), natural gas (PTI New Delhi, 2020), and CO2 emissions (Ashwini Hingne, 2018) respectively were gathered for Indian markets.

To create arrays of random variations of the key prices, price range boundaries were introduced using typical OECD values.

83 instances were used to create a large enough sample of values to determine the effect of each price on the overall revenues.

Excel Formulae Used:

Equations 1-3 show the formulae used to generate evenly distributed samples of the possible values of each price for natural gas (USD/MMBtu), electricity ($/kWh) and CO2 emissions ($/t CO2) respectively.

=RANDBETWEEN(1,10) (1)

=RANDBETWEEN(-1,35)/100 (2)

=RANDBETWEEN(0,300) (3)

The revenues (USD/t CO2) produced from processing 1 tonne of CO2 was then calculated for each of the 83 cases created using the above formulae. Equation 4 lays out the formula.

$$Revenues = (Price_{NG} \times G) + (Price_{CO2} \times C) - (Price_{Elec} \times E)$$

Where G is the number of MMBtu of natural gas produced from one tonne of CO2, C is the cost of emission of 1 tonne of CO2 and E is the number of kWhe required for electrolytic hydrogen production to convert 1 tonne of CO2 into methane.

Graphical comparison

Scatter graphs were created within Excel to plot the calculated revenues against each of the different prices. Trendlines were added to reveal the impact of each price. In addition to visual comparison, the R2 feature of Excel charts was used to quantitively compare the charts.

Results and Discussion:

Figures 2-4 show the results of the analysis.

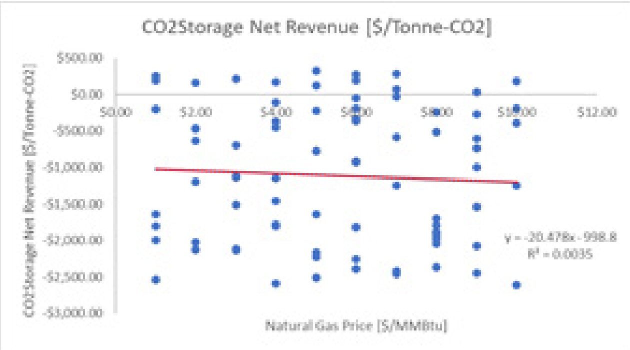

Figure 2: The effect of the change in the price of natural gas on the revenues created from operation of the CO2 Storage PtG system.

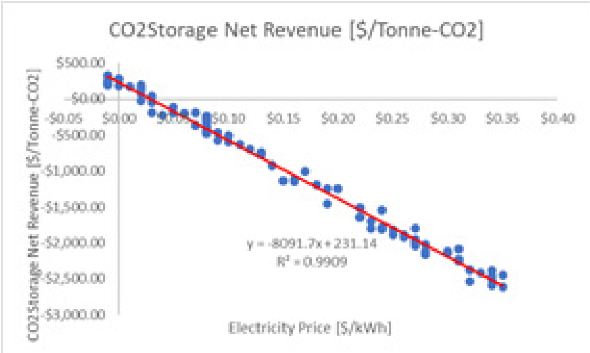

Figure 3: The effect of the change in the price of electricity on the revenues created from operation of the CO2 Storage PtG system.

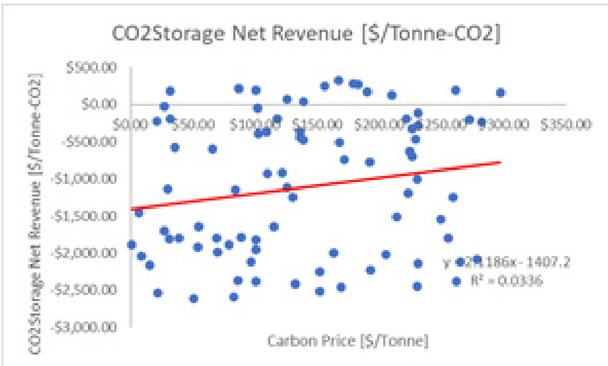

Figure 4: The effect of the change in the price of CO2 emissions on the revenues created from operation of the CO2 Storage PtG system.

Visual inspection, along with comparison of the R2 values, reveals that the correlation of revenues with electricity greatly outweighs any effect of the other prices on this key quantity.

Conclusion:

A cost-sensitivity analysis of the impact of variation in price of natural gas, CO2 emissions and electricity on PtG systems which consume the latter to produce the two former commodities was carried out. The effect of changes in the price of electricity was found to greatly outweigh the effect of variation in the prices of the other two commodities. The implications of this finding are that while carbon pricing is important for the transition to a renewable energy economy, this is not the primary driver of change. Governments and utility regulatory agencies should focus their work on creating real-time electricity markets that will enable energy storage technologies to capitalize on moments of surplus electricity production and purchase electricity at low costs.

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