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SHOULD STATE-OWNED COAL COMPANIES HARNESS GREEN HYDROGEN?

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Key Insights

` - The levelized cost of hydrogen (LCOH) for green hydrogen is estimated at $2.88/kg when using electricity from an on-grid solar PV system (Optimistic Scenario). However, when electricity is taken from RE-RTC, the cost comes to around $4.35/kg (Reference Scenario).

- Capital expenditure (CAPEX) and utilities (electricity and water) constitute the biggest cost components in the entire green hydrogen production life cycle, cumulatively accounting for 96 per cent of the total cost. CAPEX alone constitutes nearly 16 per cent of the total cost, while utilities take up nearly 80 per cent.

- Potential consumers of green hydrogen like the steel industry may not find the current estimated price viable in the absence of a subsidy or carbon tax. Currently, the cost of producing 1 kg of grey steel is around $0.32. However, the cost of producing green steel would be $0.5723 using green hydrogen even under the Reference Scenario (see Appendix for calculation), which makes the production of green steel 1.78 times more expensive.

- There is uncertainty about the immediate utilization of any green hydrogen that may be produced, given that the consumer market has not matured and infrastructure for hydrogen transportation is still inadequate.

Key recommendations for coal SoEs

- Our analysis shows that green hydrogen produced using solar is currently the cheapest option (Optimistic Scenario). Therefore, coal SoEs should invest in solar-based technology if green hydrogen, out of all the other renwable energy (RE) options considered for this study like wind, small hydro, nuclear and renewable energy round-the-clock (RE-RTC), is to be a part of their business diversification strategy.

- When the debt-to-equity ratio for funding projects decreases, the levelized cost of green hydrogen increases. For a debt-to-equity ratio of 70:30, the cost of hydrogen production comes out to be $4.35/kg. Therefore, coal SoEs should keep the debt-to-equity ratio of 70:30 as a part of capital budgeting.

- Coal SoEs should invest in high-capacity plants with better capacity factors as a way to reduce the long-term cost of hydrogen production. However, even after factoring in a subsidy, green hydrogen is still not cost-competitive.[1]

- Green hydrogen plants should be located in places with surplus electricity, which could be used to produce green hydrogen at a relatively low price.

- Green hydrogen plants must be located in places with a ready consumer base. For instance, proximity to the steel industry or a refinery should be preferred.

- To further reduce costs, abandoned coal mine lands with large quantities of water could be repurposed for the development of hydrogen plants.

1.0 Introduction

Green hydrogen has the potential to play a vital role in decarbonizing hard-to-abate sectors like steel and cement, which are otherwise difficult to electrify.[2] To harness the potential of green hydrogen and achieve its climate goals, the Government of India launched the National Green Hydrogen Mission in 2023 with many ambitious goals. For example, it has set the ambitious target to annually produce 5 million metric tons (MMT) of green hydrogen by 2030. Private companies like Reliance Industries, Adani Group, and Tata Power, as well as state-owned companies (SoEs) in the power and oil and gas sectors, are leading the charge on green hydrogen-based pilot projects.

However, the foray of coal mining SoEs into green hydrogen has barely begun. The Ministry of Coal (MoC) promotes the business diversification of its SoEs into different sectors, and has identified green hydrogen production as one of the key sectors. It has also joined hands with the Ministry of New and Renewable Energy to take up projects on green ammonia and green hydrogen. Coal India Limited (CIL)—the largest coal mining company in India and the world—has identified land parcels for undertaking a feasibility study.

Furthermore, coal SoEs like CIL or Singareni Collieries Company Limited (SCCL) are in possession of large swathes of land and huge amounts of water in their active and abandoned mines—both critical for setting up a hydrogen plant. For example, coal SoEs collectively generate over 900 million kiloliters of water every year. Moreover, CIL alone possess land of over 2.6 lakh hectares. The land and water could be used for establishing renewable energy like solar, and the abandoned mine water could be used to produce hydrogen.[3]

To assess the financial feasibility of green hydrogen, we create a financial model to estimate the levelized cost of hydrogen (LCOH) for green hydrogen, considering current government incentives and other relevant factors. Based on this analysis, we then provide insights and recommendations for coal SOEs interested in business diversification into green hydrogen.

The report is divided in the following manner. In the next section (2), we explain the methodology adopted for calculation, followed by section 3 where a brief description of the technical and financial parameters is presented. Section 4 presents the results, including incentive calculation, and in section 5 we list our limitations.

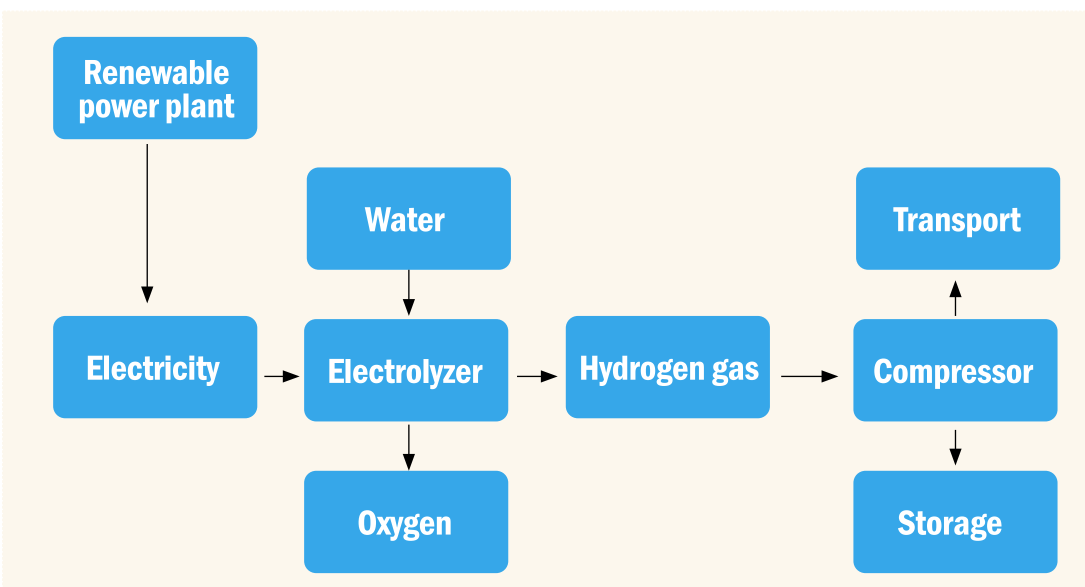
2.0 Methodology for calculating the levelized cost (LCOH) of green hydrogen

Water electrolysis is the basic method used to produce green hydrogen. This process involves the separation of water molecules into their constituent hydrogen and oxygen atoms using electricity. A systematic block diagram for green hydrogen production is presented in Figure 1.[4]

The LCOH of green hydrogen has been calculated using the following three steps:

- Firstly, we have used the National Renewable Energy Laboratory (NREL)'s Hydrogen Analysis Production Model, which calculates the levelized cost of green hydrogen production. NREL is a research and development center funded and overseen by the United States Department of Energy.
- Next, we modified numerous parameters for the Indian context, the NREL model uses an 8 per cent tax nominal internal rate of return (IRR). However, in India, it is currently 12 per cent per Government of India norms.
- Finally, we conducted several consultations with officials of Indian coal SoEs like CIL and SCCL as well as other sectoral, financial, and technical experts on all our parameters to ensure that our input cost assumptions and calculations were in line with current industry standards.

Figure 1: A systematic diagram for green hydrogen production



3.0 Technical and financial parameters

NREL's Hydrogen Analysis Production Model, which is the basis of this study, provides a brief description of the process design and a cost analysis methodology, using a discounted cash flow methodology. To carry out cost analysis, the model uses a combination of technical and financial parameters, such as type of financing, plant life, desired rate of return, among others. These parameters have been adapted to suit the Indian context. Also, our model considers two scenarios—Optimistic and Reference—to asses the LCOH. The Optimistic Scenario assumes power supply through on-grid solar photovoltaic (PV), while Reference scenario assumes power supply through RE-RTC. The details of the technical and financial parameters are provided in the subsequent sections..

3.1 Technical parameters

The green hydrogen plant for our case study has a design capacity of 500 metric tons per day (MTD), using a low-pressure alkaline electrolyzer. However, this electrolyzer has three modules, hence every module is capable of producing 167 MTD of green hydrogen. Therefore, the analysis is taken up for 167 MTD only. The technical parameters used in this analysis are presented in Table 1, and the details of the low-pressure alkaline electrolyzer are presented in Table 2.[5]

Table 1: Technical parameters considered for green hydrogen plant

Parameters	Value
Operating capacity (%)	90
Plant design capacity (kg of H_2 per day)	167,000
Plant output (kg/day)	150,300
Plant output (kg/year)	54,859,500
Plant life (years)	40
Analysis period (years)	40

Table 2: Parameters for the Alkaline electrolyzer

Technology basis	Alkaline electrolyzer
Cell Voltage (BOL Rated) (V)	2
Number of modules	3
Cathode Pressure (bar)	1.3
Total electrical usage (kWh/kg)	58
Total direct cost ($/kW)	633
Total Indirect cost ($/kW)	133

3.2 Financial parameters

The data for financial parameters, such as internal rate of return, inflation, corporate tax, etc., are mentioned in Table 3. These parameters have been standardized as per the Indian context.

Using these technical parameters and financial parameters, financial modelling was developed to predict the levelized cost of green hydrogen. In the result section, the analysis is explained for the Reference Scenario unless otherwise stated. In the case of the Reference Scenario the green hydrogen plant is configured with RE-RTC (Renewable Energy Round-the-Clock), whereas in the case of the Optimistic Scenario it is configured with an on-grid solar photovoltaic (PV) system.

Table 3: Key financial parameters considered for assessment

Parameter	Value	Rationale
Average labour burden rate	$10 (human hour)	Based on earnings per man shift for CIL at Rs 6,500 ($78) per 8 hours
Staff employed	60	NREL model[6]
Working capital	15%	NREL model[6]
Corporate tax	25%	Income Tax Department[7]
IRR	12%	Referred from NTPC Ltd[8]
Inflation rate	5.51%	As per the Department of Economic Affairs, 2024
Depreciation type	Written-down value (WDV) method	NREL has used MACRS (modified accelerated cost recovery system), which is prevalent in the USA. In keeping with the practice in India, the 'written-down value (WDV) method' has been used to calculate depreciation
Interest rate on debt	9%	Marginal cost of fund-based lending rate (MCLR) as per State Bank of India (SBI) dated May 2024[9]
Equity financing	30%	Ministry of Coal[10]
Cost of land	$7,692/acre (₹641,052.6/acre)	As per the current rate in the Bhatgaon mining area in Surajpur district, Chhattisgarh
Electricity (from RE-RTC)	$0.059 /kWh (₹4.95/kWh)	Referred from CEA[11]

4.0 Results

We estimate that the LCOH of green hydrogen production is \$4.35/kg for 167 MTD under the Reference Scenario. However, the cost is \$2.88/kg when configured with on-grid solar. A comparison between the two cases is presented in Figure 2. The cost of green hydrogen could be brought down in various ways. These include reducing the cost of electricity using RE-RTC, better electrolyzer efficiency, large design capacity, etc.

Our estimate is comparable to past estimates by scholars. Other researchers have estimated the cost of green hydrogen as \$4.45/kg and \$2.31/kg; our current analysis shows the LCOH to be \$4.35/kg.[1,5]

We found that the highest proportion of the cost (around 80 per cent) is related to utilities like electricity and water. Another major cost is the capital cost, which consists 16 per cent of the total cost during the entire operational period.

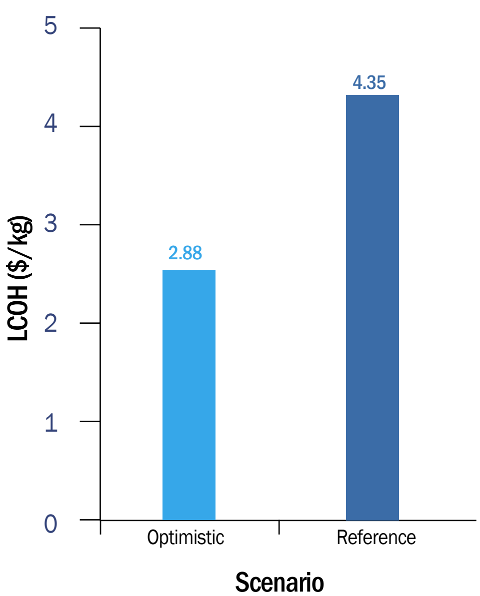
4.1 Variation of cost in different scenarios

This section explores several scenarios where different inputs can lead to cost variations.

4.1.1 Variation in the LCOH due to different sources of power generation

The cost of operation might vary depending on the source of power generation, with source referring to different types of energy systems, either renewable or non-renewable.[12] The result in Figure 3 shows that as the source of energy is changed, the cost of green hydrogen also changes. The cost of green hydrogen from on-grid solar is \$2.88/kg (under the Optimistic Scenario), and \$4.35/kg (under Reference Scenario).

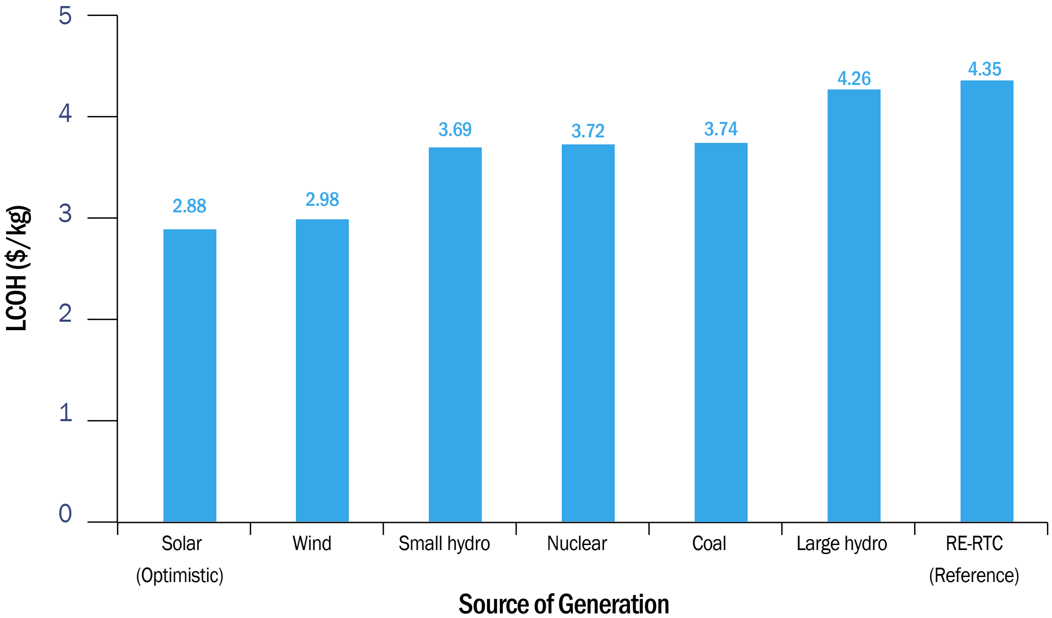
Figure 2: Cost comparison between two different scenarios



4.1.2 Variation in debt-to-equity ratio

Our analysis assumes a debt-to-equity ratio of 70:30. However, as the debt-to-ratio decreases, the LCOH shows an increasing trend. The reason for this is that as the debt-to-equity ratio decreases, the equity factor increases, which ultimately leads to an increase in the capital cost. The trend of LCOH with variation in debt-to-equity is presented in Table 4.

Figure 3: Variation of costs for green hydrogen with different power sources



4.2 Projecting LCOH based on new plant design capacity

To understand the LCOH for different capacities of hydrogen production, we have integrated the standard scaling factor method in this financial model.[13] The scaling factor is presented below:

Scaled Cost = Baseline Cost * Scale Ratio $^{\text{Scaling Factor Exponent}}$, where

- Scaled Cost is the cost of a new plant whose cost has to be determined;
- The baseline cost is the cost of the base plant which is 500 MTD (divided into three modules of 167 MTD each);
- The scale ratio is the ratio between the new and base plants; and lastly,
- Scaling Factor Exponent is assumed as 0.6.[6]

This "Scaled Cost" becomes the new capital cost, and then following the principle

Table 4: Variation in LCOH with varying debt-to-equity scenarios

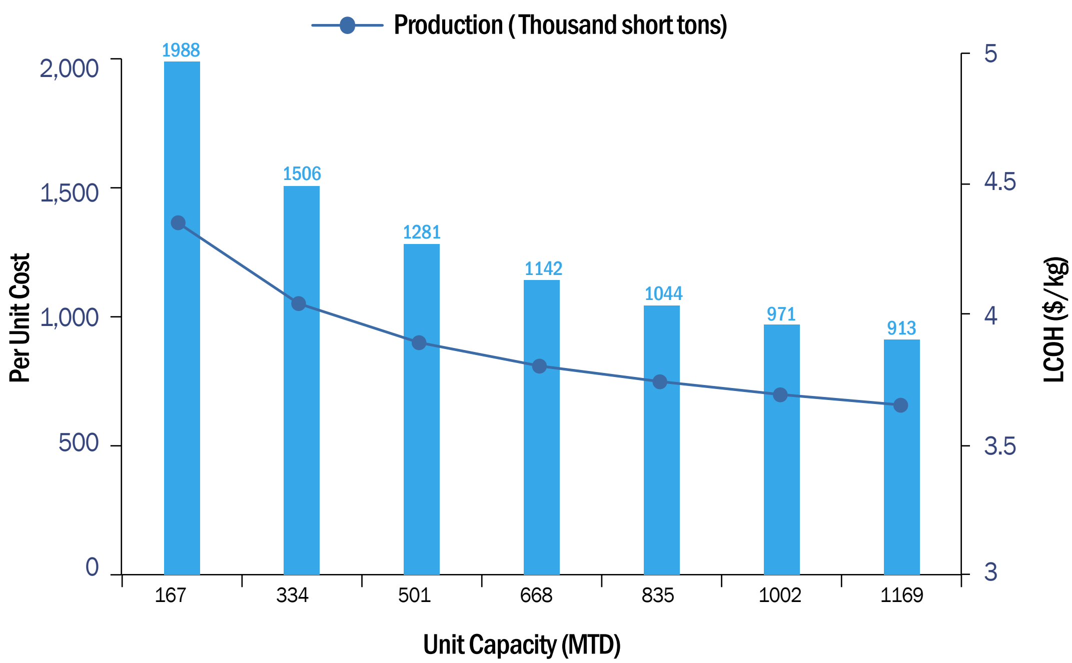
Debt	Equity	LCOH (2023) $/kg
70	30	4.35
60	40	4.47
50	50	4.58

of discounted cash flow, LCOH is calculated. Figure 4 presents the variation of unit cost and LCOH (Reference Scenario) with different plant capacities. The lowest capacity is 167 MTD, while the highest is 1169 MTD. From Figure 4, it is clear that by increasing the plant capacity, the unit cost of the plant decreases because of economies of scale. This also decreases the LCOH. Therefore, the higher the capacity of the plant, the cheaper the cost of hydrogen production will be.

4.3 Subsidy options for green hydrogen

Under the National Green Hydrogen mission, the government has launched the Strategic Interventions for the Green Hydrogen Transition (SIGHT) program. It has two components—SIGHT component I and SIGHT component II. SIGHT component I is related to the development of electrolyzers, while SIGHT component II deals with hydrogen production capacity. Since the focus of this report is green hydrogen production by coal

Figure 4: Variation of unit cost and LCOH for new plant design capacity



SOEs, we have considered only SIGHT component II, which is a production-linked incentive. In addition to national government incentives, various states have come up with incentive policies for green hydrogen, prominent among them the capital cost subsidies offered by states. However, the state level incentives are not included in the scope of this study

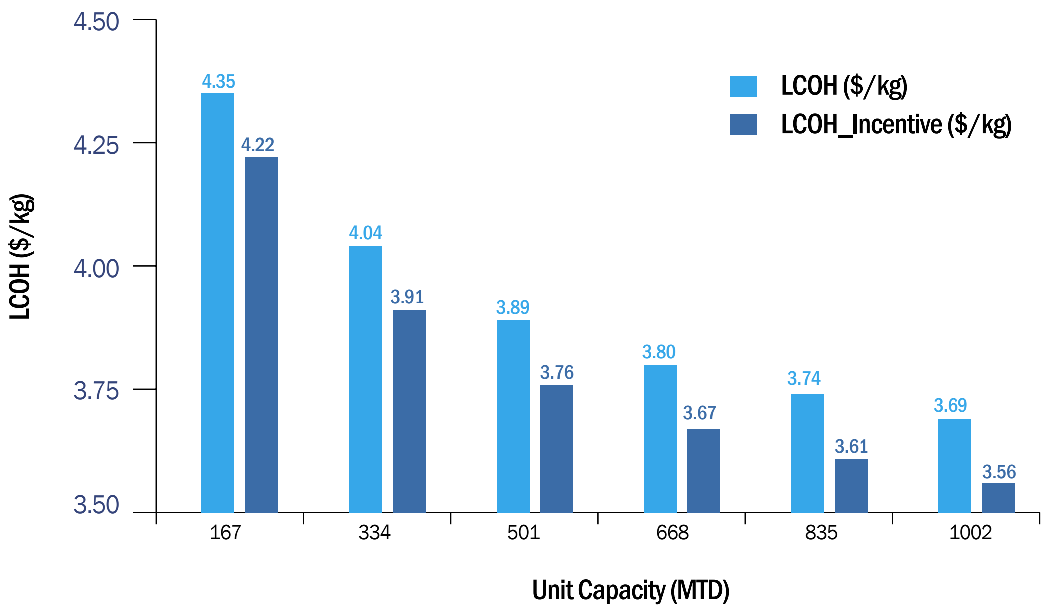
Under the SIGHT II component, the maximum cap is ₹50/kg ($0.599/kg) in the first year of production, ₹40/kg ($0.479/kg) in the second year of production, and ₹30/kg

($0.360/kg) in the third year of production. For this analysis, we have assumed 167 MTD of green hydrogen production, with a maximum cap of ₹50/kg ($0.599/kg) in the first year of production, ₹40/kg ($0.479/kg) in the second year of production and ₹30/kg ($0.360/kg) in the third year of production. All the data for maximum cap has been referred from MNRE.[14] After factoring in the incentives, the cost of green hydrogen production comes down from $4.35/kg to $4.22/kg.

Furthermore, the incentives are also analyzed for other capacity factors, and the result is presented in Figure 5.

The results show that the current incentives regime, while useful, is not enough to make green hydrogen cost-competitive.

Figure 5: Effect of incentive calculation on LCOH for 167MTD, 334 MTD and 501 MTD



5.0 Limitations of the study

- The financial analysis has been carried out for ideal conditions; that is, it has been assumed that any hydrogen produced will be consumed at the source.
- Transportation costs for hydrogen have not been accounted for. Typically, a network of pipelines or liquefaction plants and transport containers are required in order to transport hydrogen.
- The study does not assess the buyer base, or market scenarios such as demand and current supply status.
- No state-level taxation or subsidy has been considered. Only a national corporate tax has been taken into account.
- The study does not include any national- or state-level fiscal or non-fiscal incentives.
- Lastly, the specific energy consumption of the electrolyzer is considered as 58 kWh/kgH_2, and assumed constant throughout its life. However, energy consumption varies between BOL (beginning of life) and EOL (end of life).

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Appendix: Cost of green steel production

Cost components	Value
Cost of 1 kg steel	$0.32
Hydrogen required for 1 ton of steel	58 kg
Hydrogen required for 1 kg of steel	0.058 kg
Cost of green hydrogen as per analysis	$4.35/kg
Cost of green hydrogen for 1 kg of steel	$0.2523
Total cost of green steel	$0.5723

Cost calculation:

Cost of green hydrogen per kg of steel = Cost of green hydrogen from the analysis * Hydrogen required per kg of steel

Total cost of green steel = Cost of steel per kg + Cost of green hydrogen used per kg of steel

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