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List of Acronyms

CRF	Capital recovery factor
GAAP	Generally accepted accounting principles
H2A-Lite	Hydrogen Analysis Lite Production Model
H2FAST	Hydrogen Financial Analysis Scenario Tool
MACRS	Modified Accelerated Cost Recovery System
NREL	National Renewable Energy Laboratory
OCED	Office of Clean Energy Demonstrations
ProFAST	Production Financial Analysis Scenario Tool
SOFR	Secured Overnight Financing Rate
WACC	Weighted average cost of capital

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Introduction

This report provides updated generally accepted accounting principles (GAAP) parameter estimates of assumptions that may be used to reflect the cost of financing hydrogen infrastructure deployment. The report also provides parameter estimation for more streamlined financial analysis frameworks such as discounted cash flow and annualized financial models. Parameter values are derived from industry input and communication with the Office of Clean Energy Demonstrations (OCED) within the 2023–2024 timeframe. They are reflective of current macro-economic factors such as higher interest rates and higher risk profiles of emerging hydrogen technologies, given a myriad of factors such as projects' construction inexperience, capital costs, and rising inflation, among others.

Capital Structure

Capital structure refers to all cash flows associated with financing the up-front investment needed for a project, as well as for any subsequent financing needs, such as expenditures on major plant refurbishments. Capital structure covers two major categories of financing: debt and equity (Baker and Martin 2011). These sources of capital have significantly different characteristics that are relevant to their use in project financing.

Debt Financing

Debt financing typically reflects funding from risk-averse sources. Debt lenders provide funds expecting a very low probability of losing their investment (Corporate Finance Institute [CFI], n.d.-a). To provide additional security, debt lenders ensure the ability to recover their investment if a business fails. For example, in the case of a bankruptcy, businesses are liquidated, and debt lenders are given priority over equity investors (Wall Street Prep 2024) in recovering their principal. To further protect debt funds, debt lenders will impose contractual loan covenants that act as guard rails for the debt investment. Covenants may cover debt-to-asset ratios and financial performance to alert a lender if a business is at risk of defaulting or if a company's assets may not have sufficient liquidation value in a bankruptcy (CFI, n.d.-b). Debt lenders will also require businesses to carry a significant cash reserve to help maintain business operations during market fluctuations. In general, debt lenders will assign more restrictive covenants to businesses that are perceived to be higher risk. Additionally, interest rates will be higher to compensate for the higher risk of failure.

Debt financing can be desirable both to borrowers and existing equity investors given its low financing cost relative to equity and its ability to magnify the rate of return for equity investors. However, debt financing carries significant risk for project owners because debt lenders reserve the right to recall a loan or bond. A recall can be initiated if the lender perceives that the borrower is (i) not able to repay the principal, (ii) in violation of covenants, or (iii) unable to pay its interest obligations. Such conditions can emerge over the life of a project due to macro market conditions, upsets in operational supply, market offtake, or equipment failure. Businesses and debt lenders typically balance out the benefits and risks of debt financing by limiting the percentage of financing coming from debt. If a business does not achieve its financial performance and is unable to pay its interest, it can trigger bankruptcy—a debt finance mechanism for recovering a debt investment. Business cases deemed to be at a higher risk level are typically financed at a lower debt-to-equity ratio, thus reducing the relative amount of debt. To maximize the benefit of lower borrowing costs, businesses often borrow debt in the form of corporate bonds, a method that allows the borrower to maintain a constant outstanding debt throughout the period of performance, thus maintaining a high degree of financial leverage for the duration of the financing period. Borrowers prefer bond finance over loan arrangements, as it increases returns to equity investors over a longer period, but borrowers also have to balance the debt with equity financing, which does not carry the risk of bankruptcy liquidation. From a debt lender perspective, bonds are also desirable, because they reduce the administrative burden to reinvest any repayment cash flows (Securities and Exchange Commission, n.d.).

Equity Financing

The second type of capital structure, equity financing, is significantly riskier to investors than debt financing. Equity financing is often expressed as cash raised by the sale of corporate shares (CFI, n.d.-c, Coyle 2002). Unlike debt lenders, shareholders providing equity financing typically do not have a direct means of recovering funds by liquidating the underlying business. Equity returns are often realized in the form of share valuation growth driven by market performance and/or by dividend payments from the business. More speculatively, the share value can fluctuate based on a company's perceived outlook. In techno-economic modeling, financial analysis tools such as the National Renewable Energy Laboratory's (NREL's) Hydrogen Financial Analysis Scenario Tool (H2FAST, NREL, n.d.-b) and the Hydrogen Analysis Lite Production Model (H2A-Lite, NREL, n.d.-a) have historically used a default internal rate of equity returns of ~8% to 10% (Personal Communication 2024), which has been a reflection of existing market performance of specialty gas industries. The aforementioned NREL tools specifically focus on financial performance in terms of equity returns through cash flow that exceed working capital, i.e., cash-on-hand. This method of quantification precludes larger corporate strategies for retained earnings such as reinvestments in the business or investing in other financial instruments. As there is no prescribed repayment schedule for equity financing akin to debt interest, equity provides a significant degree of operational flexibility for the business—along with a higher level of risk to investors, who would be subordinate to debt lenders in asset liquidations in the event of bankruptcy (Chen 2021).

Because equity financing bears higher financial risks, investors expect return on equity to be higher than debt interest rate. In techno-economic analysis, such returns are expressed as the net present value of equity investments and cash flows that exceed cash reserves. The discount rate at which the net present value of equity equals zero is, by convention, deemed to be the rate of return to equity investors over the project analysis period. Financial models, such as H2FAST and H2A-Lite, estimate a levelized value of hydrogen such that the cash flows to equity lenders yield a net present value of zero at the specified discount rate.

Financial Analysis Parameter Values

Financing Parameters for GAAP

In the past, financial performance parameters for hydrogen projects were informed by the industry's financial performance in the hydrogen production and distribution sector. Such an approach captured the industry's actual financial performance while avoiding heightened hurdle rates used for investment decisions. Publicly traded companies have reporting requirements to the Security and Exchange Commission in the form of annual reports, which disclose aggregate financial performance, outstanding debt, equity, interest rates, and return on equity. While this approach is sensible for assessing business-as-usual markets, it does not necessarily reflect costs associated with nascent industries that bear higher risks. Based on interactions with companies facing the realities of financing clean hydrogen projects and recent increases in market interest rates, Table 1 summarizes values that could be adopted for hydrogen projects.

Note that in Table 1, parameters are provided on both a nominal and real basis. Most financial analysis is performed on a nominal basis such that prices fluctuate according to inflation. However, it is often desirable to perform analysis on a real basis, which precludes such inflation impacts. This could particularly be useful when performing techno-economic analysis and investigating the cost change impacts associated with factors other than inflation rates, e.g., technological advancements, incentive effects, etc. It also precludes inaccurately projecting inflation in future. In such a case, rates of return on debt and equity are also adjusted based on the presumed inflation rate (NREL 2023). While the long-term inflation target for the U.S. Federal Reserve is approximately 2% (Federal Reserve 2020), we apply a rate of 2.5% throughout the lifetime of the equipment based upon a more conservative view that accounts for higher inflation in recent years and aligns with NREL's Annual Technology Baseline (NREL 2023).

Financing Parameters for Simplified Frameworks

Weighted Average Cost of Capital (WACC)

In non-GAAP analysis, simplified financial calculations are based on a singular discount rate used in calculating free cash flow. This term should not be confused with the equity discount rate or return on equity used in GAAP analysis. The correct interpretation for discount rate in non-GAAP analysis is the use of weighted average cost of capital (WACC) (NREL 2023). The WACC formulation is shown in Equation 1:

$$WACC = E * Re + D * I * (1 - T) \qquad \text{(Equation 1)}$$

where:

E = fraction of total finance sourced from equity

Re = return on equity

D = fraction of total finance sourced from debt tools

I = interest rate

T = total income tax rate

Note that this method underestimates the degree of financial leverage associated with bond debt versus loan debt, as there is no parameterization to account for the debt repayment profile. With this cost of finance articulation, the WACC values consistent with Table 1 are 10% and 7.6% on a nominal and real basis, respectively (see Table 1). The real WACC value as well as the real interest rate and return on equity, reported in Table 1, are calculated based on an assumed inflation rate of 2.5%. The debt-to-equity ratio is then calculated using the nominal values of WACC, interest rate and return on equity. The real interest rate and return on equity are calculated as follows:

$$Real\ value = \frac{Nominal\ value + 1}{Inflation\ rate + 1} - 1 \qquad \text{(Equation 2)}$$

The nominal WACC of 10% for electrolyzers is reasonable based on conversations with government and industry (e.g., Hydrogen Hub awardees, hydrogen technologies stakeholders, etc.), and matches published values by the International Renewable Energy Agency (2020) and the International Energy Agency (2023). Based on the nominal values presented in Table 1, and Equation 1, we calculate the percentage of debt and equity as 38.5% and 61.5%, respectively.

It is worth noting that a nominal WACC of 10% is higher than the WACC for renewables because renewable electrolytic hydrogen projects are considered higher risk. As the production technology matures, the WACC for hydrogen projects is expected to decrease over time.

Table 1. Hydrogen Project Financial Parameters for Use with Singular or GAAP-Based Financial Models, Frameworks, and Other Applications[a]

	Nominal Basis Value	**Real Basis Value**
Inflation Rate	2.5%	0%
Interest Rate	7.0%	4.4%
Return on Equity[b]	13.0%	10.2%
Weighted Average Cost of Capital (WACC)	10.0%	7.6%
30-Year Capital Recovery Factor (CRF)	10.6%	8.5%
	Value	
Debt Type	bond debt	
Debt/Equity Ratio	0.62	
% Debt	38.5%	
% Equity	61.5%	
Total Tax Rate	25.7%	
Capital Gains Tax	15%	
Depreciation Schedule	7-year Modified Accelerated Cost Recovery System (MACRS)	
Cash-On-Hand Reserve[c]	3 months of operating expenses[d]	

[a] Application examples include H2FAST, ProFAST, H2A-Lite, NREL's Annual Technology Baseline, and HDSAM. Note: H2A-Lite is intended to operate on real basis parameters.

[b] The capital structure assumption for this report is that return on equity on a nominal basis is 13% based on OCED industry communications. The interest rate observed in hydrogen projects was similarly found to be 7% on average. Lastly, the nominal WACC was 10%. Converting nominal to real-basis financials requires an assumption of inflation rate which will lead to a different set of real-basis financial parameter values. For instance, assuming an inflation rate of 1.9% and adjusting the values to real basis result in: WACC = 8.1%, return on investment = 10.9% and interest rate = 5%. Assuming an inflation rate of 2.5%, results in the real-basis values in Table 1.

[c] Refers to cash outside short-term borrowing or reinvestments.

[d] Note that values of higher liquidity reserves are unlikely to be cash but rather would be part of interest-bearing accounts.

Interest Rate

The nominal interest rate of 7% shown in Table 1 is in line with Secured Overnight Financing Rate (SOFR) Data (Federal Reserve Bank of New York, 2024), used as zero risk interest rate. Any risk exposure is quantified and added to the SOFR. In 2023, the SOFR averaged approximately 5%. Projects with a very low risk profile would have a slight premium over this interest rate, and higher risk projects would have a higher premium. The risk premium for corporate bonds is related to the bond credit ratings of the borrower (Fidelity, 2024), AAA being the lowest risk and typically representing debt issued to municipal projects, utilities, and such that have taxes and rate structures almost guaranteeing repayment of debt. Higher interest rates are assigned to borrowers with ratings lower than AAA. A 7% nominal interest rate implies that assessed risk for hydrogen carries a 2% premium over SOFR.

Return on Equity

The nominal return on equity of 13%, derived from industry input and communication with OCED, is dependent on the business case being capable of achieving financial performance with some projected rate of equity returns. Individual equity investors judge investments and their perceived risk and decide whether to invest or not. Those investors would expect a return greater than the interest rate. The authors of this work are not aware of any standard metrics such as SOFR and bond ratings to provide a specific relationship between risk and threshold for investment. However, a number of considerations are typically factored into individual equity investing decision return thresholds such as market segment of interest, strategic interests in technology, and individual investor conservatism. It is noteworthy that within OCED communications with industry, elevated perceived risk was reported across both green and fossil-based hydrogen production pathways. While green pathways have technological and market risks, fossil pathways also carry increased risk due to future policy impacts and technological risks of carbon capture and sequestration.

Capital Recovery Factor

Lastly, some financial analyses use the most abstracted treatment of financial measures, i.e., performing annualization of all expenses and not considering multiple years of financial calculations. The key parameter for the cost of financing of capital is the capital recovery factor (NREL 2022). The capital recovery factor is defined in Equation 3:

$$CRF = WACC * \left[\frac{1}{\left(1 - \frac{1}{(1+WACC)^t}\right)}\right] \qquad \text{(Equation 3)}$$

Where CRF is the capital recovery factor and WACC can be on either a real or nominal basis, and t is the length of the useful life of the analyzed hydrogen infrastructure. Using the H2A-Lite standard useful life of 30 years and the WACC values in Table 1, the nominal CRF is 10.6% and the real CRF is 8.5%.

Depreciation and Appreciation

Depreciation Method

Tangible assets such as electrolyzers, pressure vessels, piping, compressors, and fuel cells depreciate in value over time. Recovering the cost of asset usage over time happens through either an annual income tax deduction or depreciation (Internal Revenue Service [IRS] 2023a).

In the United States, the most common depreciation method adopted is the Modified Accelerated Cost Recovery System (MACRS). MACRS assures a standardized procedure to calculate depreciation by using classification of property, which determines the depreciation rate and recovery period of an asset (IRS 2023b). In NREL financial tools such as H2FAST, H2A-Lite, and ProFAST (NREL, n.d.-c), the depreciation rates and recovery periods are precoded, and the models determine the corresponding MACRS depreciation schedule based on the quarter the asset comes into service.

MACRS provides a uniform method for all taxpayers to compute the depreciation. Using the basis, class life, and the MACRS tables, an asset deduction can be computed for the year it is placed in service and each subsequent year of its class life (IRS, n.d.). Assets such as solar, wind, geothermal, other renewable generation technologies, and fuel cells are eligible for a five-year recovery period. Any property that does not have a class life and is not otherwise classified could qualify for a seven-year recovery period (IRS 2023b), which could be a preferred depreciation period for hydrogen projects. Further, a property could be qualified for a bonus depreciation, which represents an additional depreciation allowance in the first year of the tax deductions.

Appreciation of Nondepreciable Assets

Unlike depreciable assets, nondepreciable assets might not lose value over time—possibly the opposite. They could appreciate, meaning that they may retain value or even be worth more at the end of a project. Appreciation occurs because of increased demand, decreased supply, and changes in inflation or interest rates, among other reasons (Hayes 2022). Because many of these factors are difficult to estimate, as a basis value increase, an annual inflation rate of 2.5% (NREL 2023) could be used in calculating the appreciated value of a nondepreciable asset. For hydrogen systems, such assets could be geologic storage formations, land, and rights of way.

Capital Gains Tax for Value of Appreciated Assets

Capital gains (or losses) could be defined as the difference between an asset selling price at the end of its life and the same asset's purchase price at the beginning of its life. It could be short-term if an asset has been held for a year or less, or long-term if an asset has been held for more than a year before it is retired. A typical 15% capital gains rate applies if taxable income is within low and high set thresholds, and 20% capital gains applies if the taxable income exceeds the high thresholds (IRS 2024). For multiyear projects in the hydrogen context, a long-term capital gains rate of 15% is recommended.

Decommissioning and Salvage Value Treatment

Salvage value, or scrap value, refers to the estimated value of an asset at the end of its useful life and after depreciation is complete. Salvage value is an essential element in estimating yearly depreciation. To estimate the salvage value of an asset, a business can either (i) use a percentage of the asset's investment cost, (ii) obtain an independent third-party appraisal of the asset, or (iii) collect specific asset information from industry (Kenton 2023). H2FAST, for instance, accounts for the nondepreciated assets and allows disposition as sale or loss.

Concluding Remarks

In this report, we have provided a concise overview of the most important hydrogen project financial parameters and their values, i.e., WACC of 10% on a nominal basis, debt-to-equity ratio of 0.62, and 7-year MACRS depreciation schedule, among others. Use of these financial parameters across techno-economic models will assure consistency in evaluating the economic potential of hydrogen projects.

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