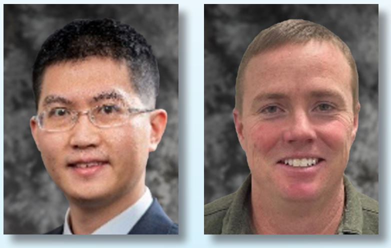
Simple Calculator Evaluates Nuclear Hydrogen Market Opportunities



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Flexible Plant Operation and
Generation Pathway

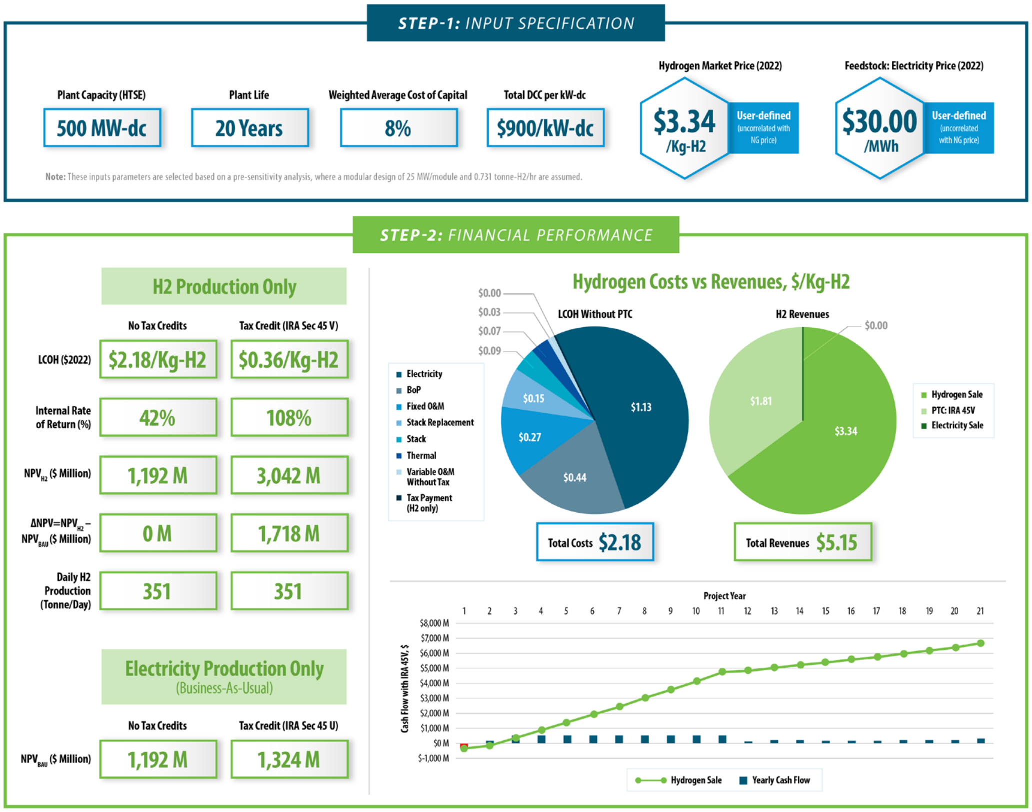
Currently, the U.S. generates around 10 million metric tonnes of hydrogen per year, but as the nation works to implement sustainable energy systems, the U.S. hydrogen market demand could increase to 96 million metric tonnes of clean hydrogen per year. Hydrogen is currently used in ammonia plants, petroleum refineries, and steel-making for iron ore reduction and for chemicals production such as methanol. In the future hydrogen could be combined with carbon sources to make bulk synthetic transportation fuels

Currently hydrogen is produced by reacting steam with natural gas, in a well-developed process called steam methane reforming, evolving carbon dioxide, a greenhouse gas, in the process. In addition, the extraction of natural gas from underground is often associated with fugitive greenhouse gas emissions. At increased cost, carbon dioxide from the steam methane reforming process could be captured and sequestered in underground geological formations to reduce the carbon intensity.

One alternative to steam methane reforming and carbon capture and sequestration is water or steam electrolysis. Low-temperature electrolysis requires water and electricity, while high-temperature electrolysis requires electricity, steam, and heat. High-temperature electrolysis is more efficient than low-temperature electrolysis because of its ability to use heat energy directly, avoiding electrical generation losses for some of the input energy. If the electricity used for electrolysis is provided by wind, solar, geothermal or nuclear energy, then the hydrogen product does not result in any significant level of greenhouse gas emissions.

Nuclear energy from existing U.S. light water reactors can efficiently vaporize water into steam for use in high-temperature electrolysis. U.S. LWRs provide a reliable source of energy that can operate reliably and continuously 24/7, all year without any interruption in hydrogen production.

Figure 4. Integrated Hydrogen Production Analysis 's (NIHPA) main dashboard is a graphical interface that displays input specifications and financial performance indicators.



STEP-1: INPUT SPECIFICATION

Plant Capacity (HTSE)	Plant Life	Weighted Average Cost of Capital	Total DCC per kW-dc	Hydrogen Market Price (2022)	Feedstock: Electricity Price (2022)
500 MW-dc	20 Years	8%	$900/kW-dc	$3.34 /Kg-H2 User-defined (uncorrelated with NG price)	$30.00 /MWh User-defined (uncorrelated with NG price)

Note: These inputs parameters are selected based on a pre-sensitivity analysis, where a modular design of 25 MW/module and 0.731 tonne-H2/hr are assumed.

STEP-2: FINANCIAL PERFORMANCE

H2 Production Only

	No Tax Credits	Tax Credit (IRA Sec 45 V)
LCOH ($2022)	$2.18/Kg-H2	$0.36/Kg-H2
Internal Rate of Return (%)	42%	108%
NPV_{H2} ($ Million)	1,192 M	3,042 M
$\Delta NPV = NPV_{H2} - NPV_{BAU}$ ($ Million)	0 M	1,718 M
Daily H2 Production (Tonne/Day)	351	351

Electricity Production Only
(Business-As-Usual)

	No Tax Credits	Tax Credit (IRA Sec 45 U)
NPV_{BAU} ($ Million)	1,192 M	1,324 M

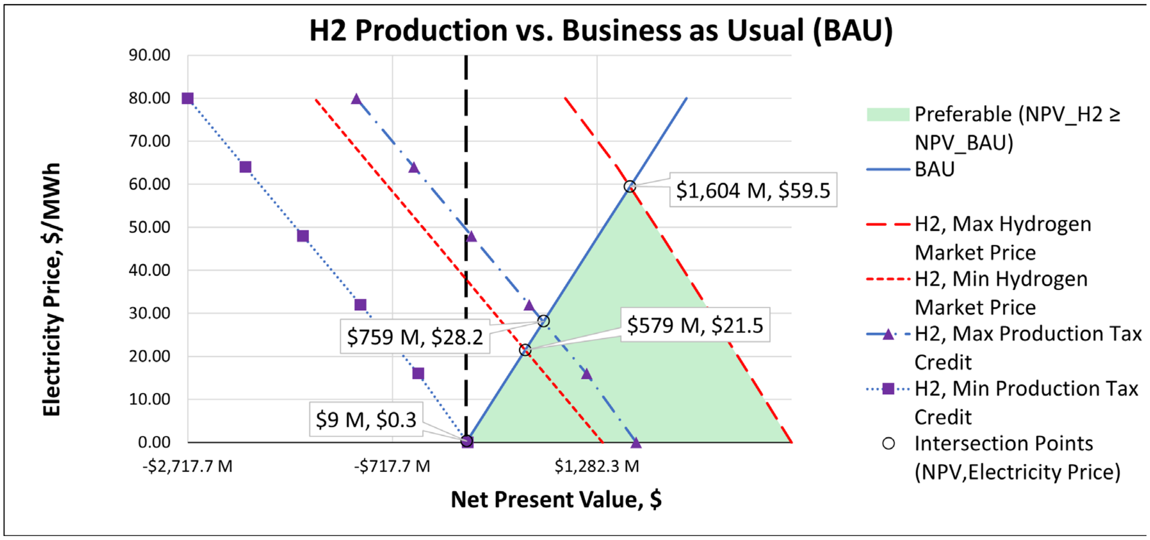


Figure 5. Decision points for choosing hydrogen production versus business-as-usual, showing a variety of potential hydrogen sale price points.

All or a portion of the energy from existing nuclear reactors' can be directed to hydrogen production throughout the year, and the amount can be optimized with local electricity market conditions.

The U.S. Congress passed the Bipartisan Infrastructure Law and the Inflation Reduction Act which provides significant incentives to build new hydrogen plants to produce clean hydrogen. These incentives also help drive down the costs of clean hydrogen production through funding research and development of electrolysis technology.

Nuclear power plants could technically switch from producing hydrogen to producing electricity as needed. However, the decision whether to produce electricity for the grid or to make clean hydrogen is not easy for utilities, grid operators or public utility commissions. If a nuclear plant is mostly dedicated to producing hydrogen, then a new source of power generation may be needed for producing electricity.

To better assist decision-makers in understanding the financial benefits of producing hydrogen, LWRS Program researchers at INL have developed a Microsoft Excel-based tool called Nuclear-Integrated Hydrogen Production Analysis. The tool allows decision-makers to input parameters such as the wholesale price of electricity to compute the cost of hydrogen production. Other user-adjustable parameters include the size of the electrolysis plant, the value of federal or state production tax credits, and other parameters for a capitalized project such as project life and the interest rate on borrowed money. The tool then displays the cost and other financial indicators with various graphical representations that make it easy for the user to interpret the results, as shown in Figure 4.

The NIHPA tool also automatically updates graphics and figures to show the value of switching to hydrogen production versus continuing the business-as-usual selling of electricity to the grid, as indicated in Figure 5.

This new calculator allows reactor operators, utility planners and industrial hydrogen users to evaluate hydrogen production costs and tradeoffs based on electricity, natural gas, and commodity market prices. While this tool has the flexibility to receive up to 50 different inputs, which can selectively be unveiled by the user, its more basic standard configuration provides utilities with enough information to compare two basic outputs—the revenue from hydrogen production and the revenue from electricity production—with a high degree of confidence.

Simple instructions are provided in the program to help users quickly become familiar with the tool and the output fields and charts. LWRS Program technical staff are also available to provide user assistance on an individual, group, or company basis.

Once users have a better understanding of the cost of hydrogen production, a deeper analysis of location- and region-specific markets can be evaluated using more sophisticated time-dependent statistical computational tools that have been developed by INL. These computational tools include Tool for Economic AnaLysis (TEAL) and Holistic Energy Resource Optimization Network (HERON), which are solved under a systems optimization computation framework known as Framework Optimization of ResourCes and Economics (FORCE). TEAL performs cash flow analysis while HERON provides optimized solutions with lowest costs and highest revenue for dispatching the electricity, steam and hydrogen depending on the customer's demand in a python-based environment.