Energize™ - Optimize Your Green Hydrogen Production

Introduction

Verdagy's proprietary techno-economic modeling platform, Energize, enables comprehensive design, optimization, and analysis of entire green hydrogen projects with unparalleled flexibility and precision. Unlike conventional modeling tools that focus solely on electrolyzer performance, Energize employs a holistic simulation engine, seamlessly integrating Verdagy's Dynamic AWE eDynamic® electrolyzers with the customer's unique needs, and operational constraints to provide an optimal green hydrogen plant design that achieves the lowest Levelized Cost of Hydrogen (LCOH) and maximizes overall project returns.

Why Energize? Overcoming Hydrogen Project Hurdles

Large-scale hydrogen investments represent significant capital risk, with interdependent systems that are complex to optimize collectively. Traditional modeling approaches struggle with accurately predicting performance when integrating variable renewable energy sources, leading to suboptimal designs, oversized components, and inflated costs that ultimately impact project viability. To address these critical industry challenges, Verdagy developed Energize, which offers:

1. Ecosystem Solution: A versatile simulation engine that models everything from polarization curves to integrated GW-scale projects, providing high-fidelity analysis of green hydrogen ecosystems through an intuitive interface. This comprehensive approach ensures that all components of a hydrogen production facility optimally work together, from power generation to hydrogen storage.

2. Customer Value Creation: Rapid, precise techno-economic analysis reduces investment uncertainty for capital-intensive hydrogen deployments. By providing detailed insights into plant economics and performance before significant capital is committed, Energize helps customers make informed decisions with confidence, minimizing financial risk while maximizing returns.

3. Plant Operation: The platform supports the development and testing of control algorithms, simulation and optimization of maintenance cycles. This enables predictive maintenance scheduling and operational optimization to maximize uptime and efficiency.

Key Differentiators

Energize distinguishes itself from other models through its holistic approach of optimizing the entire green hydrogen value chain. Energize considers every plant element, including renewables

integration, battery storage, cost of renewables, molecule storage, engineering, procurement and construction costs, operational costs, time-based energy profiles, and electrolyzer operations in 1-minute increments. This ensures customers optimize their assets, utilization and expenditures. Energize's key differentiating capabilities include:

1. Comprehensive Plant Design Optimization: Energize models hydrogen production with a detailed, bottom-up methodology by utilizing electrolyzer stack efficiency curves and integrating the electrolyzer with every other plant element such as renewables, grid, battery storage, and hydrogen storage to provide a realistic and granular simulation of actual plant operations and enable optimal asset utilization and the lowest LCOH.

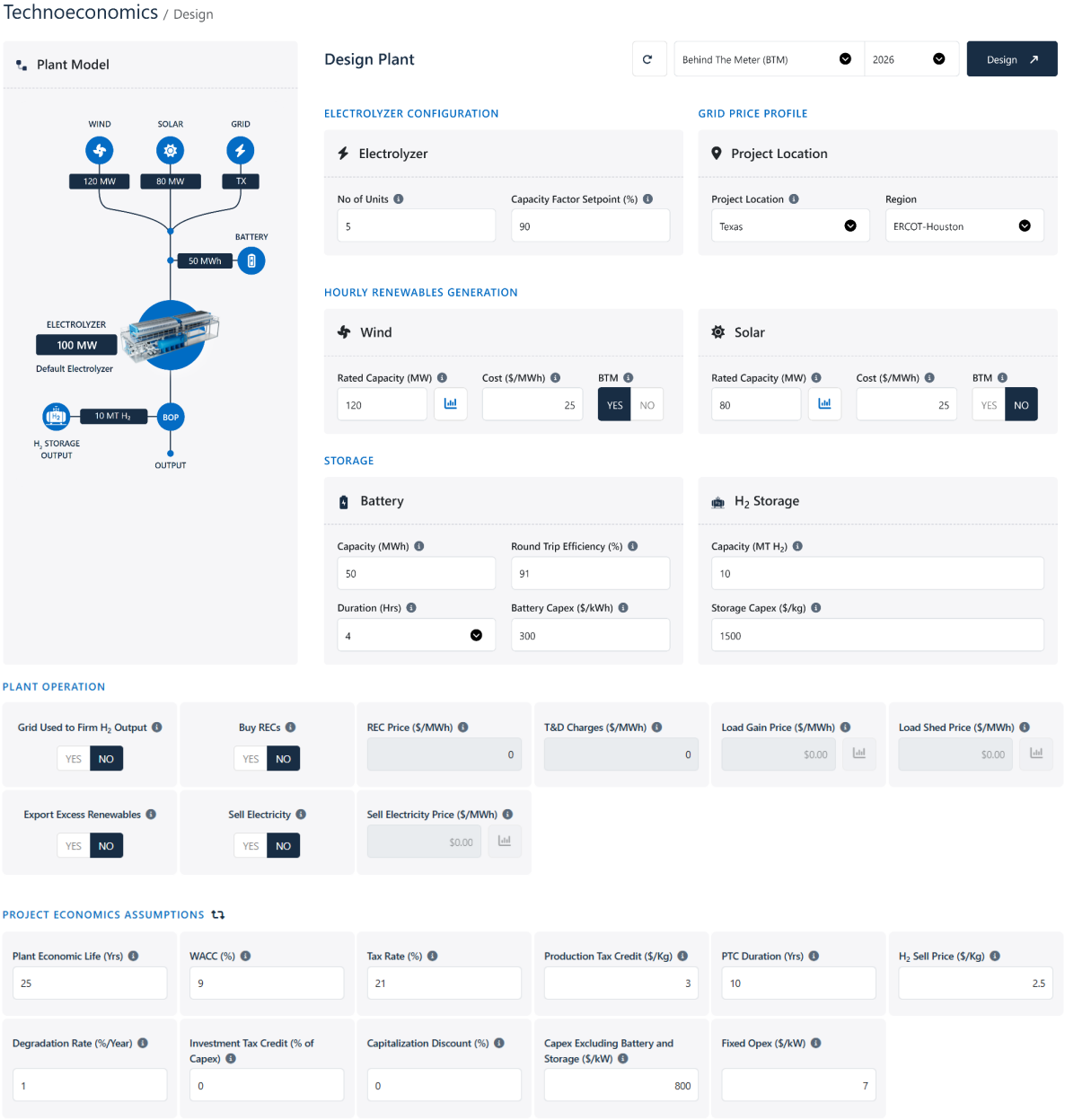

Figure 1: Energize's intuitive user interface and plant digital twin paired with pre-configured inputs, enables rapid and comprehensive plant design

2. Sub-Hourly Simulation: Energize unlocks sub-hourly plant operations with granularity down to the minute enabling near real-time plant operation simulation. Sub-hourly simulations allow the electrolyzers to rapidly respond to power supply fluctuations, especially renewables, to demonstrate their full potential.

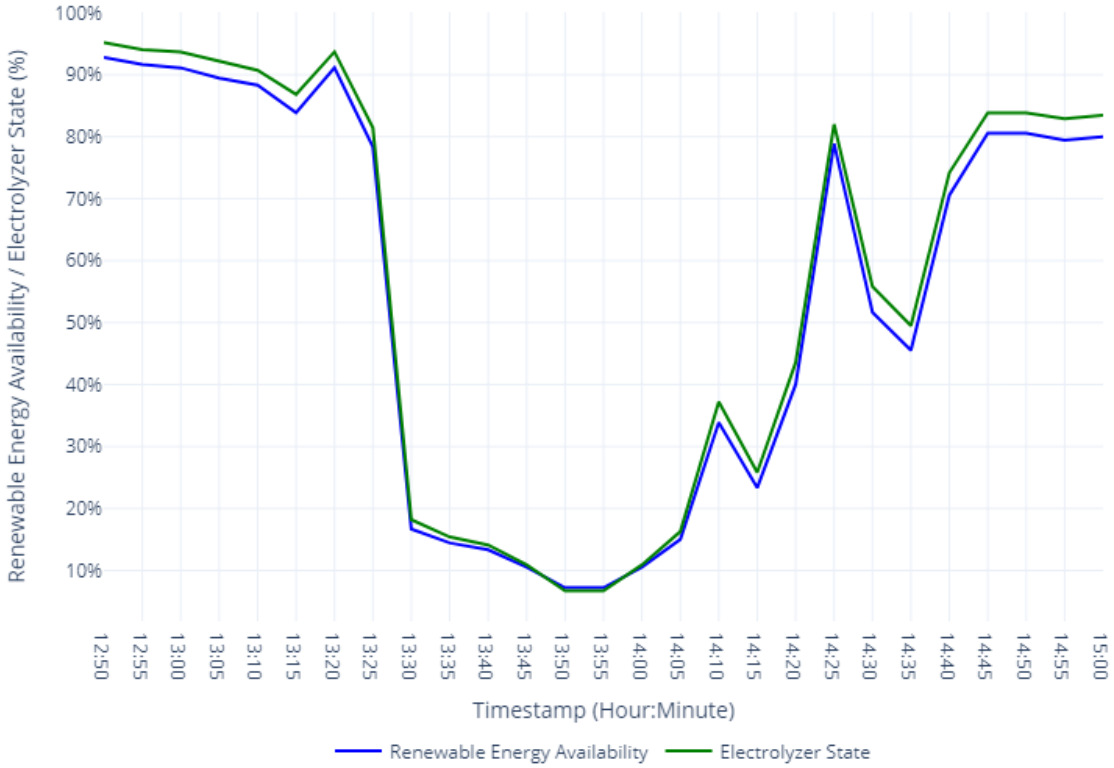

Figure 2: Energize's simulation of Verdagy's Dynamic AWE eDynamic load following ability and low turndown capability at 5-minute intervals

3. Advanced Plant Operation and Energy Arbitrage: Energize offers advanced grid-connected plant operation modes that leverage Verdagy's eDynamic electrolyzer technology, including exporting excess renewable energy and selling energy or "load shedding" above a threshold market price. Complementing these energy arbitrage capabilities, Energize enables sophisticated "load gaining" strategies wherein the plant automatically increases hydrogen production when electricity prices fall below a specified threshold—a patented plant process and operation controls capability made possible by Verdagy's industry-leading turndown ratio and rapid response time. By strategically consuming cheaper power, the plant effectively averages down its overall energy cost per kilogram of hydrogen produced, thereby optimizing economics, enhancing profitability, and building resilience against market volatility.

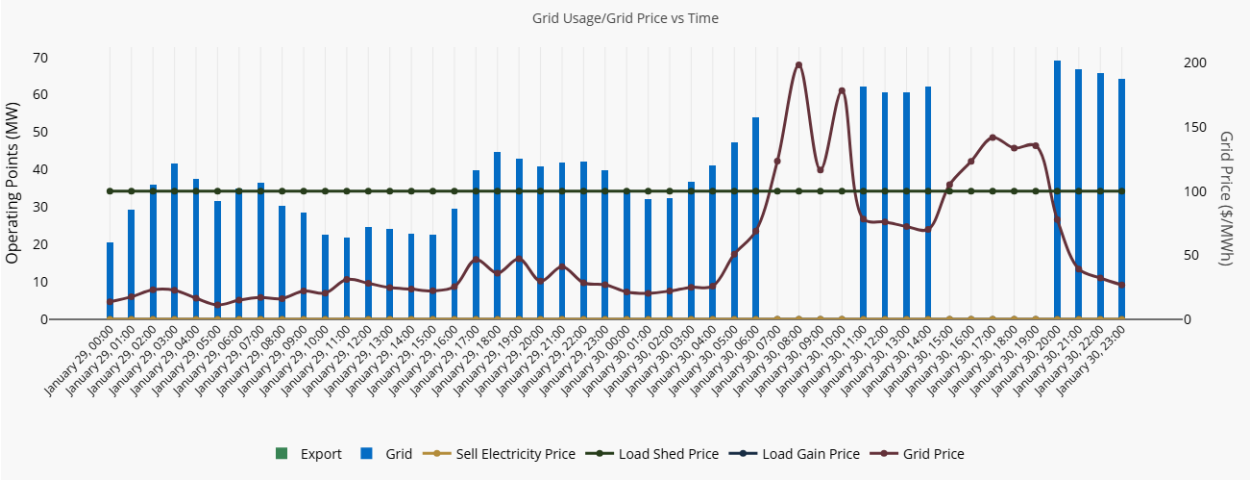

Figure 3: Energize's smart grid consumption with load shedding above $100/MWh threshold grid price

4. Advanced Sensitivity Analysis: Beyond the standard modeling capabilities available in the public version, Energize offers several advanced sensitivity analysis features through the back-end model, such as parameter sweeps and cost curves, to help explore various scenarios, fine-tune existing components and identify further optimizations.

Case Study

To demonstrate the practical power of Energize in modeling large-scale green hydrogen projects, this section explores a sample case study for a hypothetical 400 MW electrolyzer plant planned for operation in 2030, situated in the ERCOT market (Texas), targeting 45,000 TPA (metric tons per annum) green hydrogen production and powered by dedicated solar and wind Power Purchase Agreements (PPAs). For compliance with EU standards of Renewable Fuels of Non-Biological Origin (RFNBO) and eligibility of the full $3/kg-$H_2$ Clean Hydrogen Production Tax Credit (45V) under the US Inflation Reduction Act (IRA), grid consumption was not considered for this case study.

Figure 4: Techno-economics summary for a 400 MW electrolyzer plant in 2030 with Verdagy[1]

[1] ~3X renewables oversizing (~70% wind / 30% solar mix) compared to electrolyzer capacity assumed to optimally meet target H2 production. Wind and solar PPA cost assumed to be $28/MWh and $35/MWh respectively (Source: NREL State and Local Planning for Energy, TX LCOE). 96% set-point capacity factor assumed for plant availability consideration.

PLANT OPERATION

Grid Used to Firm H_2 Output	Buy RECs	REC Price ($/MWh)	T&D Charges ($/MWh)	Load Gain Price ($/MWh)	Load Shed Price ($/MWh)
No	No	0	0	NA	NA

Export Excess Renewables	Sell Electricity	Sell Electricity Price ($/MWh)
Yes	Yes	47.6

PROJECT ECONOMICS ASSUMPTIONS

Plant Economic Life (Yrs)	WACC (%)	Tax Rate (%)	Production Tax Credit ($/Kg)	PTC Duration (Yrs)	H_2 Sell Price ($/Kg)
25	9	21	3	10	2.5

Degradation Rate (%/Year)	Investment Tax Credit (% of Capex)	Capitalization Discount (%)	Capex Excluding Battery and Storage ($/kW)	Fixed Opex ($/kW)
1	0	0	750	5

Figure 5: Key case study inputs and assumptions[2]

The techno-economic analysis presented by Energize in Figure 4 provides key performance indicators, including average plant efficiency over the first operational year. It's important to note that this average plant efficiency is for reporting purposes only. On the back end, Energize models electrolyzer efficiency dynamically using detailed curves based on instantaneous load. This precise approach further capitalizes Verdagy's superior efficiency at lower loads, utilizing Verdagy's industry-leading turndown capability within the simulation to maximize hydrogen yield, especially from intermittent power inputs, across the widest possible operating range.

While this case study focuses on a 2030 scenario, Verdagy is committed to a continuous cost reduction roadmap for its Dynamic AWE eDynamic electrolysis technology and integrated plant designs before and beyond 2030, driven by ongoing innovation, manufacturing scale-up, and supply chain optimization. Verdagy's goal, supported by the optimization capabilities of Energize, is to accelerate the path towards green hydrogen achieving cost parity with fossil fuel-based hydrogen, making large-scale decarbonization economically viable.

Summary

Verdagy's Energize platform offers a unique, comprehensive, and data-driven approach to make informed decisions, minimize risks, and maximize returns, establishing itself as an indispensable tool for green hydrogen project development.

Energize delivers granular insights at gigawatt scale, enabling users to visualize hourly plant operations, iteratively refine system sizing, and optimize project economics with unprecedented precision. The platform's sophisticated architecture - designed with modularity and extensibility at its core - supports analysis from hourly down to minute-by-minute timescales, making it equally valuable from small pilot installations to massive industrial deployments. Energize provides the

[2] Excess renewable generation traded at marginal energy cost for H2 production. Capex assumption includes electrolyzer stacks, power supply, Balance of Stack (BoS) and Balance of Plant (BoP) equipment, spare parts and service tools, freight, and engineering, procurement and construction (EPC) cost estimates. Fixed Opex assumption includes BoS and BoP preventative maintenance cost estimates incurred by the plant operator. (Source: Verdagy Analysis)

detailed modeling capabilities necessary to drive confident investment decisions and operational excellence at every stage of development.

Energize stands out with its modern architecture with an intuitive front-end user interface and a suite of powerful features designed to minimize the LCOH and maximize profitability. Please click here to try Energize and here to contact us.

Nisarg Kanani, Techno-Economic Analytics Manager, Verdagy

Karan Doss, PhD, Staff Software Engineer, Verdagy