Introduction

➔ EnergyTag is non-profit helping define and promoting 24/7.

➔ Years experience in Hydrogen Industry. Worked on hourly matched electrolyser project design.

➔ EnergyTag has supported Co-signed [letter](#) in US and EU supporting robust rules for clean hydrogen production.
Clean Hydrogen Needs 3-Pillar Clean Electricity

Principles of 24/7 Carbon-Free Energy

24/7 Carbon-Free Energy means that every kilowatt-hour of electricity consumption is met with carbon-free electricity sources at every hour of every day, everywhere. It is based on the following principles:

- **Time-matched procurement**: matching hourly electricity consumption with carbon-free electricity generation. Hourly matching helps connect clean energy purchasing to underlying electricity consumption.

- **Local procurement**: purchasing clean energy on the local/regional electricity grids where electricity consumption occurs. This is the only way to drive the electricity-related emissions that a consumer is directly responsible for to zero.

- **Technology-inclusive**: recognizing the need to create zero-carbon electricity systems as quickly as possible. All Carbon-Free Energy technologies can play a role in creating this future.

- **Enabling new generation**: focusing on delivering additional Carbon-Free Energy to drive the rapid decarbonization of electricity systems.

- **Maximizing system impact**: addressing the dirtiest hours of electricity consumption where the most fossil fuel is used in generation.

Source: UN 24/7 Compact
EU Hydrogen Will be 3-Pillar Hydrogen

➔ All Renewable Hydrogen produced in **and imported to EU** will be 3-pillar from 2030.

➔ Transition to hourly could have been shorter. But EU tracking legislation needs updating. **US has no such block.**

➔ **Deviations** from three pillars in **US would be have more serious emissions consequences** as 1) no carbon price 2) dirtier grids and 3) much larger subsidy.

➔ Hydrogen Europe **stated** "These strict rules can be met" upon release of EU rules.

➔ Projects announcements have increased since announcement of the rules.

*Source: European Commission*
Growing Consensus that 24/7 is Truly Clean

Governments
- United States
- United Kingdom
- Scotland
- Ireland

Energy Experts
- IEA
- Technische Universität Berlin
- Princeton University
- EUI Florence School of Regulation

System Operators
- entsoe
- Alliander

EU/US NGO for Green H2
- Bellona
- Clean Air Task Force
- Client Earth
- Climate Action Network
- Deutsche Umwelthilfe
- Environmental Defense Fund
- Global Witness
- International Council on Clean Transportation
- International Council on Clean Transportation
- Natural Resource Defence Council
- Transport & Environment
- Union of Concerned Scientists.

UN Compact

118 Signatories
Hourly Matching Feasibility

➔ From experience - 3-pillar electrolysers are possible in industry.
  ◆ Air Liquide’s “Elygator”
  ◆ AES - Air Products

➔ Electrolysers should be flexible to take advantage of clean cheap power.
  ◆ PEMs can ramp in seconds (see peer reviewed data and research)

➔ Hydrogen supply can be firm with hourly matching
  ◆ Source high capacity factor clean power to match 70-100%+ of time.
  ◆ Store hydrogen (or electricity)
  ◆ Rely on existing production capacity.
Millions of MWh of hourly tracking globally, today
Hourly RECs Already Available Across the U.S

- Between M-RETs and PJM hourly RECs already available across most of the US.
- EnergyTag Standard can help harmonise hourly tracking as needed.
The U.S. “Clean” Hydrogen Battle

April 2023

Rachel Fakhry
Director of Emerging Technologies
Key Points

- High stakes: billions of $$ and potential hundreds of millions of tons of carbon missions
- It all hinges on the Biden administration
- Rigorous guardrails are necessary in the form of the three pillars – new supply, hourly matching, deliverability
- Fierce fight
CONTEXT SETTING
Hydrogen production sources

Status Quo “Grey” Hydrogen
- Natural gas
- Combustion
- Hydrogen
- CO₂

Gas-Derived Hydrogen + CCS, or “Blue” Hydrogen
- Natural gas
- Reforming
- Hydrogen
- Underground storage
- CO₂

Electrolytic Hydrogen
- Green electricity
- Water
- Hydrogen
- O₂
What is the 45V clean hydrogen tax credit?

*Production tax credit in $ per kilogram of hydrogen produced ($/kg) relative to the carbon intensity of the produced hydrogen in kilograms of carbon dioxide equivalent per kilogram of hydrogen (kgCO2e/kgH2).*
45V is a substantial and long-lived subsidy

- More than $100B over its lifetime
- AES/Air Products project in Texas: $3 Billions in subsidies (*Energy Innovation estimate*)
- Very long lived (~2045)
The implications of 45V hinge on Treasury, DOE, EPA and the White House

- Subsidy tied to the lifecycle GHGs of hydrogen production
- Treasury directed to issue guidance for calculating the lifecycle GHGs of hydrogen projects, within one year of the IRA’s enactment
- Department of Energy (DOE), Environmental Protection Agency (EPA), and the White House are closely engaged
COMPLEXITY AND RISKS
Calculating lifecycle GHG emissions can be quite tricky.

The complexity varies from project configuration to another:
- **EASY**: “Behind the meter”, not drawing power from the grid
- **MORE COMPLICATED**: Grid-connected, drawing grid power, buying credits/offsets

Need some parameters/rules around the sort of “offsets” allowed to be used.

Hydrogen projects range in complexity; projects relying on “offsets” need rigorous rules.
High risks of 45V increasing emissions if Treasury guidelines are weak

- Electrolysis is an electricity hungry process (more than 25% of electricity is lost in the process)
- Even small shares of fossil fueled electricity powering electrolysis would result in significant emissions

More than 100 million tonnes of emissions increases in this decade; equivalent to the power sector emissions of North Carolina
The three pillars: why do we need them?

- Three pillars = parameters around the credits/offsets

- Only parameters/system that ensures effective offsetting of grid emissions and that hydrogen projects are either directly or indirectly powered by clean electricity
  - Inarguable:
    - Inarguable:
      - Princeton University; Energy Innovation, Rhodium Group, MIT Energy Initiative
The three pillars are legally necessary to meet IRA requirements

- IRA defines a hydrogen project’s lifecycle emissions by referencing the Clean Air Act (implements the federal Renewable Fuel Standard)
- The analogy to 45V is clear:
  - Effectively requires Treasury to account for the systemwide emissions of hydrogen production, i.e., induced grid emissions
  - For example, if a hydrogen project drives increased fossil fuels on the grid, Treasury must account for those emissions.
- It is near impossible for a hydrogen project to meet the IRA emissions thresholds without adopting the three pillars

→ The pillars legally necessary to meet IRA requirements.
THE FIGHT
How a tax break meant to curb climate change could make it worse

Green hydrogen is branded a zero-carbon superfuel. But at the behest of big energy firms, new subsidies could go to a product with a much different climate profile.

By Evan Halper
March 3, 2023 at 6:00 a.m. EST

The great ‘green hydrogen’ battle

Tens of billions in federal tax credits could build a vital low-carbon hydrogen industry — or increase carbon emissions. We tackle the complexities in a series.

28 March 2023

The Fight to Define Green Hydrogen, With Billions of Dollars at Stake

NextEra and BP argue for looser rules on tax credits for hydrogen production

By Amrith Ramkumar and Katherine Blunt
Feb. 12, 2023 5:30 am ET

We're about to give billions of dollars to clean hydrogen. How should we define it?

A conversation with Rachel Fakhry of NRDC.

The fight to define ‘green hydrogen’ could determine America’s emissions future

The Treasury Department’s definition will affect billions of dollars in federal subsidies for the nascent industry.
Landscape of stakeholders

**Pro - 3 pillars**

- All environmental groups
- Community, local and environmental justice groups
- Hydrogen developers and OEMs (e.g., Intersect Power, Electric Hydrogen)
  - Renewable energy developers (e.g., EDP Renewables)
- Academics and research groups (e.g., Princeton University, Energy Innovation)
  - Large customers (e.g., Google)
- Registries and hourly matching organizations (e.g., M-RETS, EnergyTag)

**Anti - one or more of the 3 pillars**

- Hydrogen developers (e.g., Plug Power)
  - Utilities (e.g., NextEra)
- Renewable energy organizations (e.g., American Council for Renewable Energy, though not unanimous across members)
- Consulting firms (e.g., Wood McKenzie, E3)
Opposition to one or more of the pillars: Why?

- Anti-additionality:
  - Companies/utilities looking to use *existing* clean energy assets (e.g., existing nuclear plants) to produce hydrogen, regardless of the emissions impact of diverting this existing clean energy from the grid

- Anti-hourly matching:
  - Companies/utilities:
    - Looking to maximize subsidies and shareholder value by running an electrolyzer quasi 24/7; and/or
    - With a business model/in a region where hourly matching may not pencil out at today's electrolyzer costs (e.g., in an exclusively solar region)
THANK YOU!
Smart 45V Guidance Design to Cut Emissions and Grow Clean Hydrogen

Dan Esposito
Senior Policy Analyst

April 2023
Energy Innovation Policy & Technology LLC®

- Non-partisan climate policy think tank working with policymakers regardless of political affiliation.
- We provide objective research based on scientific assessments to identify the most effective economywide emissions reduction policies.
- We prioritize policies in the largest emitting nations and sectors, focusing on policies that accelerate technology-neutral zero-carbon solutions at the speed and scale necessary to fight climate change.
- We work towards a climate safe future where people and the planet thrive with economic, security, and equity benefits.
- Our technology-neutral policy recommendations are grounded in data, driven by our open-source and peer-reviewed Energy Policy Simulator model and our book Designing Climate Solutions.
- Twitter: @EnergyInnovLLC | LinkedIn: Energy Innovation Policy and Technology LLC
- Web: https://energyinnovation.org | Newsletters: https://energyinnovation.org/newsletters/

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Key Takeaways

Smart 45V guidance is:

▪ **Essential**
  ▪ GHG emissions impact
  ▪ Long-term clean H2 impact
▪ **Implementable**
▪ **Financially viable**
Electrolyzers' Impact on the Power Grid

**No Electrolyzer**
- 50% from fossil fuels
- 100% from renewable sources

**Dirty Electrolysis**
- 60% from fossil fuels
- 100% from renewable sources

Increase in fossil fuel power
Electrolyzers’ Impact on the Power Grid (2)
Electrolysis Emissions (No Additionality)

- Coal
- Natural gas (average tech)
- Natural gas (best tech)

$3/kg\text{H}_2$ limit

Steam methane reformation

Emissions Impact

Long-term Clean H2 Impact

Financial Viability

EMISSIONS (kg CO$_2$e / kg H$_2$)

- California
- Carolinas
- Central
- Florida
- Mid-Atlantic
- Midwest
- New England
- New York
- Northwest
- Rocky Mountains
- Southeast
- Southwest
- Tennessee
- Texas

SMR

$\$0.60/kg$

$\$3/kg$
The Solution

Clean Electrolysis

50% 100%

No increase in fossil fuel power

NEW

DELIVERABLE

TIME-MATCHED

Emissions Impact  Long-term Clean H2 Impact  Financial Viability
Loose 45V Guidance → Inflexible Systems

24/7

Run around the clock

Maximize gov’t subsidies

No need for H₂ storage
Stringent 45V Guidance → Flexible Systems

- Ramp up and down
- Fewer gov’t subsidies
- H₂ storage to firm output
Inflexible Systems – Problem

Emissions Impact

Long-term Clean H2 Impact

Financial Viability

With subsidy

Without subsidy
Inflexible Systems – Consequences

**Option 1:**
- Stranded Assets
- Lost Jobs
- Derailed Industry

**Option 2:**
- Subsidy Extension
- More GHGs
- Delayed Problem
Flexible Systems – Sustainable Growth

Variable H₂ production

Storage smooths delivery to offtaker

Without subsidy

With subsidy
Flexible Systems – Grid Benefits

Very low or negative power prices = Excess renewables = Electrolyzer online

Higher power prices = Fossil power online = Electrolyzer offline
Project Configurations

- **OFF-GRID**
- **EXPORT-ONLY**
- **DETACHED**

<table>
<thead>
<tr>
<th>Clean Energy</th>
<th>Electrolyzer</th>
<th>Sales</th>
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</thead>
<tbody>
<tr>
<td>Generation</td>
<td>Consumption</td>
<td>Excess Premium</td>
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</tbody>
</table>

- **Emissions Impact**
- **Long-term Clean H2 Impact**
- **Financial Viability**
Results

- Export-only projects can easily sell hydrogen at $1/kg and make a profit IF located in places with decent wind resources.
- Key assumptions:
  - CapEx = $1,400/kW-year
  - O&M = $90/kW-year
  - Finance + Tax Shield = $90/kW-year
  - Restricted revenue from excess power sales to the grid to keep focus on value of electrolysis.
  - Chose a low power price year to be conservative.

<table>
<thead>
<tr>
<th>Metric</th>
<th>West Texas</th>
<th>Near Houston</th>
<th>Southwest Minnesota</th>
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<tbody>
<tr>
<td>Electrolyzer capacity (MW)</td>
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<td>1</td>
<td>1</td>
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<tr>
<td>Electrolyzer capacity factor (%)</td>
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<td>81.8</td>
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<td>Solar capacity (MW)</td>
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<td>Solar capacity factor (%)</td>
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<td>20.8</td>
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<td>Solar levelized cost ($/MWh)</td>
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<tr>
<td>Wind capacity (MW)</td>
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<td>Wind capacity factor (%)</td>
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<td>Share of power sold to grid (%)</td>
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<td>Revenue from hydrogen sales and 45V (%)</td>
<td>79</td>
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<tr>
<td>Revenue from excess power sales to grid (%)</td>
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<td>Revenue from premium power sales to grid (%)</td>
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<tr>
<td>Profits ($/kW-yr)</td>
<td>143</td>
<td>85</td>
<td>61</td>
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</tbody>
</table>
Financial Viability of Compliant Projects Today
Thank you

Dan Esposito
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SMART DESIGN OF 45V HYDROGEN PRODUCTION TAX CREDIT WILL REDUCE EMISSIONS AND GROW THE INDUSTRY

DAN ESPOSITO, ERIC GIBSON, AND MIKE O'BOYLE

APRIL 2023

EXECUTIVE SUMMARY

The United States cannot achieve net-zero greenhouse gas (GHG) emissions without carbon-free hydrogen. Today, this molecule saves the chemicals and refining industries, and fossil fuel-derived hydrogen production contributes about 1.5 percent of total U.S. climate pollution. Shifting to cleaner hydrogen production can replace these dirty sources while cutting GHG emissions in industries that are hard or impossible to electrify.

Congress included a production tax credit (PTC) for clean hydrogen in Section 45V of the Inflation Reduction Act (IRA) to help scale the nascent industry. The tax credit’s value is tied to the life cycle GHG emissions of hydrogen production—including upstream emissions—with the highest tranche set at $1 per kilogram (kg) of hydrogen that is nearly emissions free.

Congress tasked the U.S. Treasury Department with deciding how hydrogen producers must account for their emissions to qualify for these incentives. Treasury accepted public comments in December 2022 and is working on final rules at the time of this paper’s publication.

This research shows loose 45V guidance could cost tens to hundreds of millions of tons of GHG emissions annually at a cost of $10 billion annually in federal funding while setting the

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Modeling Evidence: Why the Three Pillars?
Our Study

• Used **GenX** to investigate the impact of grid-based hydrogen production on **system-wide emissions** under multiple possible PTC implementations

• Used a six-zone model of the US Western interconnection as an example system, with a planning year of 2030

• Added a large electrolysis load to each zone

• Assessed the emissions impacts of this additional load under various clean energy procurement requirements
• Annual matching leads to emissions outcomes no better than making no clean energy procurements at all

• Hourly matching was the only strategy that successfully enabled H₂ production without adverse emissions impacts

• Incremental cost is fairly low
• When procurement of transmission-constrained resources is allowed, much of the benefit of hourly matching is eliminated
• Congestion prevents ‘matching’ clean resources from actually delivering power, forcing reliance on fossil
• Procurements should have a causal relationship with new resource deployments
• Allowing procurement of existing resources (or those mandated for deployment under state policy) completely undermines an hourly matching policy
• Still, enforcing ‘true’ additionality depends on knowing counterfactual outcomes and is likely impossible
A number of studies have investigated the cost of complying with the Three Pillars.

Most find that even with the Three Pillars requirements, subsidized H₂ production in the US will be competitive from day one.

Some studies disagree, and our recent LCOH intercomparison report explains why that is the case.

Most estimates of current electrolyzer facility costs fall between $700/kW and $1500/kW.
• High fixed costs or low utilization rates lead to uncompetitive projects.

• Studies that optimize the sizing of both wind and solar power find that high utilization rates are achievable under the Three Pillars.

• Oversizing renewables and selling excess clean power is a winning strategy, leading to low cost premiums.

Optimizing the mix of clean electricity resources is key to a successful Three Pillars hydrogen project.
• Even at DOE's most conservative electrolyzer cost estimates, optimized clean energy portfolios lead to cost-competitive hydrogen production under the Three Pillars.
• As costs fall, more and more projects will become competitive, and hydrogen prices will drop below $0/kg in the most ideal locations. Single-resource projects may remain uncompetitive.
• At DOE’s 2030 cost projections, utilization rates become much less important. Clean hydrogen cost therefore becomes less location-dependent.