TOPSOE

Commissioner Danny Werfel
Internal Revenue Service
U.S. Department of the Treasury
1111 Constitution Avenue NW
Washington, DC 20224

RE: Comments on “Section 45V Credit for Production of Clean Hydrogen; Section 48(a)(15) Election To Treat Clean Hydrogen Production Facilities as Energy Property,” Notice of Proposed Rulemaking and Notice of Public Hearing, 88 Federal Register 89220 (Dec. 26, 2023)

Dear Commissioner Werfel,

Topsoe commends the Treasury Department’s significant efforts, and especially the coordination with the Department of Energy and Environmental Protection Agency, on the proposed rulemaking and we appreciate this opportunity to provide input.

Company Overview

Topsoe is a leading global provider of technology and solutions for the energy transition and is currently constructing one of the world’s largest and most advanced solid oxide electrolyzer (SOEC) component factories to date in Herning, Denmark.

We combat climate change by helping our customers and partners achieve their decarbonization and emission reduction goals. Based on decades of scientific research and innovation, we offer world-leading solutions for transforming renewable resources into fuels and chemicals for a sustainable world, and for efficient and low-carbon fuel production and clean air. We were founded in 1940 and are headquartered in Denmark, with over 2,800 employees globally serving customers all around the world, including an office and a manufacturing facility in Bayport, TX.

Our ammonia solutions have supported fertilizer production that has secured food supply for growing populations, and we’ve provided the technology that reduces sulfur and other pollutants from fossil fuel emissions to environmentally safe levels. We build on these achievements when delivering solutions for the decarbonization of energy-intensive industries.

Our dedication to solving society’s biggest challenges through science and innovation is deeply rooted in our heritage. Since Dr. Haldor Topsøe founded our company in 1940, we’ve been driven by a passion for science and a determination to make a positive

change in the world. Staying true to his legacy, our purpose remains: Perfecting chemistry for a better world.

Today, Topsoe is a leader in solutions and technologies for ammonia, methanol, renewable diesel, and sustainable aviation fuel production. The company's innovation leadership directly results from nearly 9% of annual revenue being dedicated to R&D. Topsoe is one of the very few companies to offer end-to-end solutions in clean hydrogen, clean ammonia, and clean methanol. These solutions are ideal for decarbonizing hard-to-abate sectors such as chemicals production, aviation, shipping, heavy transport, and heavy industry, where direct electrification is challenging.

The company has set its own net zero targets, which have been approved by the Science-based Targets initiative (SBTi). Topsoe commits to reaching net zero across the value chain by 2040 compared to a 2020 baseline. In the near term, Topsoe commits to reduce absolute scope 1 and 2 greenhouse gas (GHG) emissions by 95% by 2030 and to increase annual sourcing of renewable electricity to 100% by 2030. Furthermore, Topsoe commits that 74% of its suppliers - by emissions covering purchased goods and services, fuel and energy related activities, and upstream transportation and distribution - will have science-based targets by 2027. The company has also joined the U.S. DOE Better Climate Challenge.

Topsoe's solid oxide electrolyzer cell (SOEC) component factory in Denmark, one of the world's largest, is scheduled to be operational by early 2025. The EU Commission recently completed a rigorous review of SOEC's technological, financial, and operational maturity and Topsoe's Danish Factory was one of 41 large-scale projects (out of 239 applications) awarded a €94 million grant from the EU Innovation Fund. The Danish Factory serves as a blueprint for a potential U.S. manufacturing expansion.

Topsoe's comments mainly address two items: (1) the need for an **additional technology pathway in the next update of the 45VH2-GREET model** that would include all types of high-temperature electrolysis, beyond the SOEC-nuclear pathway included in the current model, and (2) the **temporal matching requirements** for Energy Attribute Certificates (EACs) in proposed §1.45V-4(d)(3)(ii)(A).

These comments also share information on several available clean hydrogen production technologies for the agency's awareness and request clarity on a few issues raised in the proposed guidance.

(1) 45VH2-GREET Should Be Updated to Include a Pathway for Market-Ready SOEC Technology Paired with Waste Heat from Industrial Processes

The 45VH2-GREET model released with the proposed guidance includes only a pathway for high-temperature electrolysis paired with nuclear energy. This narrow pathway misses the valuable efficiency gains that SOECs can achieve when powered by waste heat from industrial processes such as ammonia or steel production.

Hydrogen is the only option for decarbonization in these industrial processes, meaning their uptake should be a high priority to meet climate goals.

One of the nearest term uses for SOECs is for integration with ammonia production. Topsoe has developed its own integrated SOEC-ammonia loop. This plant can be powered with fluctuating renewable electricity from wind and solar, thereby supporting grid stability and decarbonization. The efficiency performance of the SOECs is enhanced with the recycled waste heat from the ammonia loop. The entire process is carbon-free. The SOEC-ammonia loop is expected to be one of the most widespread use-cases for the SOEC technology.

Topsoe appreciates that the DOE plans to update the 45VH2-GREET model on a regular basis and that the proposed guidance would establish a process for securing a provisional emissions rate (PER). Yet given the market readiness of SOECs, Topsoe urges the DOE to prioritize adding a pathway for the SOEC technology paired with waste heat from industrial processes in the next update to the 45VH2-GREET model to eliminate uncertainty that the PER process will bring.

SOEC Overview

While the industry will need many available technologies to scale quickly, SOEC electrolyzers have several notable advantages over low-temperature electrolyzers like PEM or Alkaline:

- SOEC electrolyzers are 20% more efficient without heat integration compared with competing platforms. SOEC efficiency over low-temperature electrolysis technologies increases to 30% with heat integration.
- SOEC uses materials that are abundant in nature, reducing supply chain constraints and increasing scalability.
- SOEC is a compact stack built primarily from abundant, low-cost ceramic materials enclosed within a metal housing, improving costs and avoiding issues of material scarcity.
- SOEC can operate in a fluctuating mode to match production levels with the availability of renewable energy.

More detailed information on SOEC technology is included in the attached white paper.

The Important Role of Green Ammonia

First Ammonia will produce ammonia from renewable electricity with Topsoe’s SOEC electrolyzer at a flagship facility in Port of Victoria, Texas. This is the first commercial-scale ammonia facility to use SOEC electrolyzers. Green ammonia production will begin in 2026, with rapid scale up thereafter enabled by modular design, serving industrial and global customers.

Green ammonia is necessary to meet the growing demand for ammonia from today's fertilizer and chemical industries, displacing new coal- or natural gas-based ammonia plants. Green ammonia is also expected to be the most important hydrogen carrier for long-haul transport of green hydrogen and will also be used directly as a shipping fuel. Green ammonia's advantage stems from its 100-year history of international trade as the key ingredient in fertilizer, with records as early as 1927 discussing shipments of refrigerated ammonia from Europe to Asia.

Green ammonia will be produced from hydrogen and nitrogen by applying a Haber-Bosch synthesis loop with hydrogen from SOECs. This process will become relevant on industrial scale and several projects are already being developed in the U.S. This integrated hydrogen-ammonia loop is important for decarbonization as it runs on fluctuating levels of electricity. Where conventional ammonia loops require steady streams of electricity, Topsoe's technology harmonizes with renewables, allowing for the integration of additional renewable energy into the grid.

First Ammonia's electrolyzers will be completely operated by power that can meet the 45V proposed guidelines and do not have any other direct energy source. The recycled waste heat from the ammonia loop comes from the energy content of the hydrogen produced in the SOECs, because the ammonia synthesis is an exothermic process. The ammonia synthesis loop is a closed cycle without emission sources. The GHG intensity of the recycled heat could thus be considered zero.

Market Readiness of SOEC

The market readiness of SOEC has been validated by credible organizations.

International Energy Administration (IEA)

Recently, the IEA has upgraded the technology readiness level (TRL) of SOEC from 7 to 8. Going by established TRL definitions, this indicates that SOECs have proven their capabilities in commercial-scale demonstrations, and are also available for serial production, although at low levels. According to the IEA:

> SOEC is quickly approaching commercialization. In April 2023, a 2.6 MW SOEC electrolyzer was installed in a Neste refinery in the Netherlands, becoming the biggest at that time.[1] Just few weeks later in 2023, the record was broken with a 4 MW SOEC system installed in a NASA research centre in California. Bloom Energy increased its SOEC manufacturing capacity in 2022 with a new high-volume line in Newark, moving towards GW-scale operations in the United States.

[1] This electrolyzer is manufactured by Sunfire, which has extensive partnerships with other potential hydrogen off-takers, such as steel manufacturer Salzgitter. Salzgitter has ambitions to install 400MW of electrolyzers by 2030, to meet its ambitions of switching to 100% hydrogen-based green steel production in the early 2030s.

> Topsoe is advancing construction of an industrial-scale 500 MW/yr manufacturing facility in Denmark, expected to be online in 2025.

Clean Air Task Force (CATF)

The CATF, in its SOEC Technology Status Assessment, is optimistic regarding the technological progress that SOECs can make, given existing commercialization of the technology and increasing production rates. The report concludes (page 47):

> Solid oxide electrolyzer technology is at a higher readiness level than many give it credit for. Most of the companies that are pursuing SOEC development have already completed pilot projects, and even put their technology into commercial operation with industrial partners. […] Scaling SOEC manufacturing to meet the world's growing appetite for electrolyzers will not be a bottleneck. Experienced manufacturers with a track record can build a large, gigawatt-scale factory in less than two years and navigate supply chain risks for raw materials.
>
> […]
>
> The main advantage of SOEC technology is the step change improvement in efficiency it offers when integrated with an external process that can provide high-purity steam. This makes SOEC a perfect fit for industrial sites with enough unused low-grade process heat to evaporate water. Ammonia, chemical, and steel plants, as well as refineries, would be particularly well suited for SOEC integration. Geothermal plants are another option.
>
> […]
>
> SOEC is well positioned to be the preferred hydrogen generation technology at industrial sites with available process steam.

The Electrochemical Society and the Royal Society of Chemistry

Research published on behalf of the Electrochemical Society and Royal Society of Chemistry have supplemented the position of high-temperature electrolysis / SOEC as having or rapidly approaching a TRL of 8, with research directions now mainly oriented towards increasing efficiencies and lowering stack replacement costs, which would contribute to the commercial competitiveness of SOECs – going beyond proving commercial or technological feasibility but also efficiency improvements. The study published in the Royal Society of Chemistry is available here and the Electrochemical Society study is available here.

Strong incentives like the 45V tax credit will further accelerate scaling of hydrogen production technologies like SOEC that are critical for supporting the energy transition.

(2) Temporal Matching

The proposed guidance would require hydrogen producers to procure EACs to satisfy a temporal matching requirement. The requirement would be met if the electricity represented by the EAC is generated in the same hour that the taxpayer's hydrogen production facility uses electricity to produce hydrogen.[2]

In regions where hourly matching systems are or can be in place and sufficient renewable generation is available, such as in the ERCOT grid region, SOEC electrolyzer technology can be a market-leading solution for efficient hydrogen production under these requirements.

However, we also appreciate the proposed guidance's recognition that, "Hourly tracking systems for EACs are not yet broadly available across the country and will take some time to develop."[3] In conversations with stakeholders in the value chain who will be required to use these systems, we see different levels of achievability in different grid regions. A phase-in period for these requirements applied nationally, or an exemption until infrastructure is available, is critical.

(3) Additional Clean Hydrogen Solutions

SynCOR. In addition to SOEC, Topsoe also offers a clean hydrogen production solution called "SynCOR." The SynCOR process has low OPEX, since the reactor operates at a steam-to-carbon ratio of 0.6, which is 3–5 times less than that of steam methane reforming (SMR) or less developed conventional autothermal reforming (ATR) systems. The lower steam throughput also has the benefit of reducing equipment and piping sizes, a benefit that is most pronounced at large scale, since the equipment and piping are kept within standard size ranges – even at very large single-line capacities.

With SynCOR, external fuel demand is extremely low, hence a very high carbon-recovery rate (>99%) can be achieved without having to capture the carbon present within the flue gas. This makes SynCOR very well suited for use in clean hydrogen production.

SynCOR technology has a proven track record of over 300 combined years' industrial operation, with availability factors exceeding 99%. More than 150 years of SynCOR industrial experience have been carried out with a steam-to-carbon ratio of 0.6 or below, providing Topsoe with ample experience in this severe and demanding form of operation.

Due to this low steam-to-carbon ratio, it is economically favorable to employ SynCOR in large-scale plants. The largest SynCOR reactor currently in operation has a hydrogen production capacity of 500 kNm3/hour, and the economical limit for single-train capacity

[2] 88 Fed. Reg. at 89232.
[3] 88 Fed. Reg. at 89233.

is 825 kNm3/hour. Because of such favorable economics, SynCOR is likely to remain a dominant technology for large-scale hydrogen production in the near-term.

eREACT™ Another new hydrogen production method is Topsoe's electrified steam methane reforming, dubbed "eREACT". In this method, the main reforming reactions occur inside a catalytic reactor heated by an electrical current. This eliminates the need for hydrocarbon fuel as a heat source, which in turn eliminates reformer flue-gas emissions. The energy density of an eREACT process results in a reactor size that is a fraction of an SMR unit. Furthermore, almost all CO_2 in the shifted process gas can be recovered, at low cost, by a CO_2-removal unit, making this process an excellent candidate for clean hydrogen production in cases where electricity prices are favorable. The eREACT process has been successfully tested at pilot scale and will soon be tested in a demonstration plant.[4]

Topsoe is supporting several clean hydrogen projects announced in the US already, including:

- Exxon Mobil, Baytown, Texas – low-carbon hydrogen plant
- Ascension Clean Energy, Louisiana – low-carbon ammonia plant
- Sustainable Fuels Group and CIP, Louisiana – low-carbon ammonia plant

More information on Topsoe's clean hydrogen production technologies can be found in the attached white paper.

(4) Requests for Additional Clarity

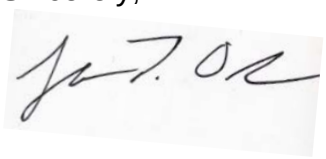
On the following issues, we ask that the final guidance provide additional clarity:

- The 45VH2-GREET model accommodates GHG emissions calculation for either fossil natural or landfill gas, but not both. In some scenarios a producer can use a mix of fossil natural gas and landfill gas to reduce GHG emissions. How could a hydrogen producer calculate the GHG emissions for such scenarios? Would the producer ask for a PER in that scenario?
- Will Treasury consider recognition in the 45VH2-GREET model for investments in using lower carbon natural gas owing to lower upstream methane leakage rates and shift that into foreground data? If so, what is the timeline for such updates?
- Where in-house electricity is produced from biogenic feedstock for hydrogen production, if the produced biogenic CO2 is captured and stored in the ground is this considered as negative carbon intensity in the 45VH2-GREET model? If not, could this option be added in the next update of 45VH2-GREET?

[4] https://www.topsoe.com/press-releases/topsoe-and-aramco-to-demonstrate-groundbreaking-low-carbon-hydrogen-production-technology

Thank you for the opportunity to provide input on this critical guidance. Please do not hesitate to reach out to me at jsol@topsoe.com with any questions.

Sincerely,



Jessica Olson
Head of Global Affairs, Americas
Global Sustainability & External Affairs