INTRODUCTORY NOTE

IEA Wind Task 11 Topical Expert Meeting 106, September 6th-7th, 2023

On

HYDROGEN IN A 100% RENEWABLE ENERGY SYSTEM

"Hydrogen is today enjoying unprecedented momentum. The world should not miss this unique chance to make hydrogen an important part of our clean and secure energy future."

IEA report The Future of Hydrogen[1],

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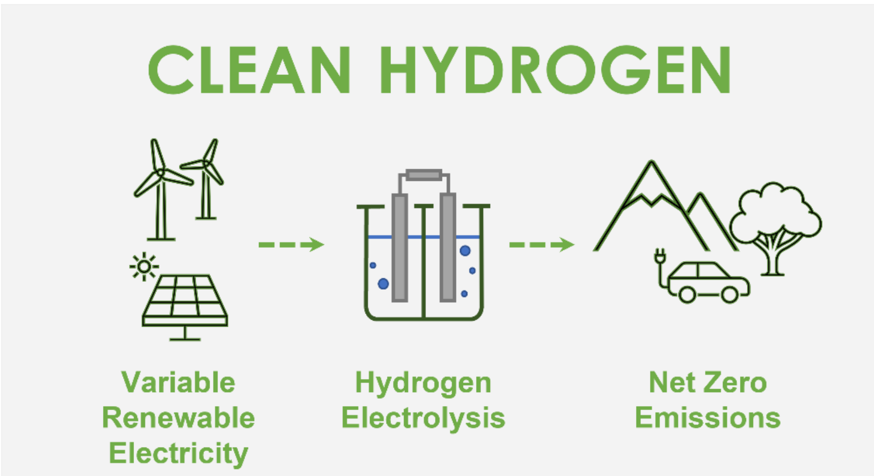

[1] IEA (2019), The Future of Hydrogen, IEA, Paris https://www.iea.org/reports/the-future-of-hydrogen, License: CC BY 4.0

1 Value for IEA Wind TCP

1.1 Background

Reaching the goal of zero greenhouse gas emissions by 2050 outlined by the IEA in the Net Zero by 2050 report[2] will require the development of clean energy technology components, system interfaces, controls, and operating procedures that will allow clean energy technologies to operate as one integrated system. The transition to clean electricity, such as wind and solar, and rapid scaling of clean fuels, including hydrogen, play essential roles in meeting this goal. Hydrogen has the potential to be used as a clean fuel in many applications such as electricity generation, energy storage, transport, industrial and chemical processes, import/export, and others.

Since the use of hydrogen has so many applications across its life cycle, from production to storage to delivery, it is essential that the future of hydrogen is addressed in a coordinated way. On the hydrogen production side, as wind and solar capacity increases as clean electricity is scaled up, hydrogen produced by electrolysers that are powered by wind and solar are a key enabler of a net zero energy system. This connection was mentioned as a potential for cost-savings, as well, in The Future of Hydrogen report[2]:

> *With declining costs for solar PV and wind generation, building electrolysers at locations with excellent renewable resource conditions could become a low-cost supply option for hydrogen, even after taking into account the transmission and distribution costs of transporting hydrogen from (often remote) renewables locations to the end-users.*

In this sector, new opportunities for research and innovation multiply as costs continue to fall, technologies improve, and emissions reduction ambitions increase. Researchers and developers in this fast-moving area need to be aware of the wider developments and potential synergies between their previously disparate sectors to maximize the potential of these technologies.

1.2 Motivation

Integration of hydrogen technologies with renewable energy covers a broad energy technology spectrum. The IEA, through its convening authority, can be used to bring scientists and researchers together for knowledge sharing and potentially collaborative research that reduces duplication of efforts, and can lead to greater outcomes overall. Seizing these opportunities, the Future of Hydrogen for 100% Renewable Energy Systems Topical Expert Meeting (TEM) will bring together experts from three Technology Collaboration Programmes (TCPs) – Hydrogen, Photovoltaic Power Systems (PVPS), and Wind – to determine future research directions and collaboration opportunities. The primary outcome of this TEM is to lay the groundwork for a cross-cutting collaboration between the Hydrogen, PVPS and Wind TCPs to inform and incentivize the development of the integrated energy systems of the future.

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[2] IEA (2021), Net Zero by 2050, IEA, Paris https://www.iea.org/reports/net-zero-by-2050, License: CC BY 4.0

1.2.1 Specific Value to IEA Wind

Higher shares of Variable Renewable Electricity (VRE) give rise to complex energy integration challenges, such as energy storage and curtailment. VRE will also likely be the largest contributor to electrolysis energy demand, allowing it to affect emissions reduction outside of the electricity sector and have added non-CO_2 environmental benefits. Other added benefits of converting VRE to hydrogen include energy security and economic development, both promoted within the IEA Wind TCP.

1.2.2 Collaboration between TCPs

The IEA promotes collaboration between the TCPs. Interdisciplinary contributions add value, reduce risk, and in this case, help to address the research priorities of the Wind TCP and of the Working Party on Renewable Energy Technologies (REWP), such as

- *Provide a platform for information exchange and discussion*
- *Review, add value to and develop shared key messages from the nine IEA TCPs which are under the umbrella of the REWP*
- *Contribute to the development of the IEA's Energy Technology Network*
- *Enhance the impact of IEA's work*

There are collaborations involving hydrogen, wind, and solar, however, these tend to either examine the topic at a high-level and highlight potential areas of synergy or focus on a particular technological niche without awareness of the wider system. This TEM will differ by trying to make independent players aware of one another's views and potential for mutual benefit. However, the normal benefits of providing an independent global forum for leading experts and researchers to leverage global government funding for international collaborative programs will also apply. The Wind TCP has been in contact with the Hydrogen and PVPS TCPs and started discussions on defining their common interests and finding the best way to collaborate, while respecting their members' engagements and priorities.

2 Meeting Format and Goals

2.1 Objectives and Ideal Outcomes

The objective of this TEM is to identify a potential research agenda to guide a cross-cutting collaboration between the Hydrogen, PVPS, and Wind TCPs. This TEM aims to narrow the scope of the discussion and move the conversation from broader awareness and siloed thinking to specific actions that can be taken. This will be achieved by encouraging focused debate on specific key issues, as opposed to technology status updates and introductions to individual research projects by members of the TCPs. There will be an opportunity for members to familiarize themselves with each other's work in advance and discuss collaborative activities giving rise to well-defined research aims.

As an outcome, the proceedings of the meeting will be published, including the identification of future R&D needs and a potential new joint or linked task between the Hydrogen, PVPS, and Wind TCPs.

2.2 Tentative Program

The TEM will be a two-day in-person meeting; however, a virtual option will be offered for the plenary sessions in listen-only mode via Fed Zoom. Preliminary surveys will allow us to amend the program to best promote productive discussion based on attendee expertise and guide attendees to sessions where they can contribute most. Focusing on a few, well-defined issues, should produce the most focused collaboration. Broadly, the interconnectedness of clean hydrogen, the potential constraints on development, recognition that optimization lies beyond a single source of electricity, and the underlying economics are the topics to be discussed. A potential tour of the NREL Flatirons campus hydrogen and renewable energy facilities could also take place the morning after the official TEM.

2.2.1 TEM format

To maximize the effectiveness of this TEM, we can survey potential participants in advance, narrowing down the topics for discussion on the day.

Below is a high-level outline of how the TEM will be run, subject to input from the organizing committee, and survey responses of the potential attendees.

Before the TEM:

- List of suitable attendees is created, updated often, wide variety of stakeholders.
- Session moderators are appointed, each session being defined and under the responsibility of one of the co-organizers.
- Potential points of discussion are generated for each session.
- Attendee list is surveyed to identify most pertinent points of discussion.
- Attendees produce a slide on them and their work to be distributed ahead of time to the other attendees.
- Access to slides, plus survey results are shared with attendees.

During the TEM:

- Each session has a brief 15-20min introduction, prepared by the moderator.
- The session is broken into group to discuss the topics.
- Each group has a chair and notetaker, nominated in advance.
- Groups are brought back together where chairs lead a 90min group summary.

After the TEM:

- The group summaries and subsequent discussions are used to detail new tasks.
- Attendees are given a final summary and the new task brief is shared.

2.2.1.1 Topic 1: Infrastructure and Grid Integration of Clean Hydrogen

Brief: *The source of electricity dictates the cost and sustainability of clean hydrogen. However, its role in the overall energy system must also be considered. This includes the infrastructure needed to support clean hydrogen production and grid integration, such as the use of storage or whether the plant is grid-connected or not.*

Producing directly from VRE guarantees the hydrogen is fully decarbonized and simplifies the supply chain but may limit the capacity factor and opportunities for shared infrastructure. Conversely, utilizing grid electricity can increase the capacity factor and allow for the provision of grid services, but PPAs and/or Guarantees of Origin are required to demonstrate sustainability, and it could be difficult to achieve the scales required.

Potential Points of Discussion within this Session

- Grid Services (optimal electrolyzer location and size)
- Hydrogen end-uses (influences for on/off grid)
- Role of storage (battery-electric and hydrogen)
- Use of existing infrastructure
- On/off grid system configurations (profitability and sensitivities)
- Timelines of plant development
- Clean hydrogen export
- Hydrogen storage (options, amount, new vs. existing)
- Hydrogen delivery (proximity of systems to demand)
- Forecasting (demand, price, and resource forecasting)
- Biofuels and non-electric H2 production

2.2.1.2 Topic 2: Systems Design and Operations of Clean Hydrogen Plants

Brief: *This topic addresses considerations of clean hydrogen on the individual plant level. The specific designs and operation of these plants will determine the overall profitability. This includes integration with various renewable energy sources and technology innovations directed towards the production of hydrogen. It also considers plant design, sizing and control.*

Potential Points of Discussion within this Session

- Co-location of variable renewable energy technologies
- Electrolysis sizing and placement in the system
- Integration with a single technology (e.g. offshore wind)
- Technology designs to benefit hydrogen production (e.g., low cut in speed wind turbine generators)
- Role of storage (battery-electric and hydrogen)
- Capacity factor vs. overall energy production
- Control strategies for an integrated plant
- Influence of the end-user on plant design (e.g. conversion services)
- Integrated power electronics (e.g. avoiding multiple DC/AC conversions.)
- Resource and demand forecasting
- Dynamic electrolyzer operation (flexibility and opportunities)
- Adding electrolysis to use curtailed energy

2.2.1.3 Topic 3: Policy and Market of Clean Hydrogen

Brief: *Competing directly with fossil fuels is incredibly difficult, particularly while their externalities are not priced in, and they continue to be subsidized. Instead, it is understood that to achieve comparable costs hydrogen requires a combination of subsidization, targeted policy measures, monetizing system benefits, and exemptions from certain taxes depending on usages. How this is achieved is up for debate, but all solutions should consider the consumer, encouraging competition and development, and sustainability.*

Potential Points of Discussion within this Session

- Protecting consumers from high energy prices
- Encouraging adoption

- Subsidizing the demand, the production, or both
- Whole systems thinking (price signaling, technology subsidization)
- Clean hydrogen uses
- System benefits of electrolysis (cost sharing)
- Social acceptance of clean hydrogen
- Current policies and their effectiveness
- Global trade

TENTATIVE PROGRAM (DRAFT)

Dates: September 6-7, 2023

Location: Boulder, CO

Day 1: 6 September 2023 (Wednesday)

Plenary Session (90 minutes) Background, Challenges and Meeting goals *(Virtual Listen-Only Supported in this session)*

- Welcome from US DOE
- Research Presentation on Clean Hydrogen project (TBD)
- Research Presentation on Clean Hydrogen project (TBD)
- Background to the Renewable Hydrogen TEM and the need to identify the needed research directions and collaboration opportunities by TEM organizers.
- IEA Wind – IEA introduction and Task 11 mission and logistics (TBD)
- IEA Wind, Hydrogen and PVPS Program Overviews
- Other Background (TBD)

Break (15 minutes)

Charter for Afternoon Breakouts (15 minutes, 15-20 participants per breakout)

Parallel Sessions: (90 minutes) Each group will discuss the area of Topic 1: Direct Production or Power from the Grid

Networking Lunch (45 minutes)

Parallel sessions: (90 minutes) Each group will discuss the area of Topic 2: Optimum Electricity Mix Considering Clean Hydrogen

Break (15 minutes)

Parallel sessions: (90 minutes) Each group will discuss the area of Topic 3: Policy and Market of Clean Hydrogen

Day 2: 7 September 2023 (Thursday)

Plenary (90 minutes): *(Virtual Listen-Only Supported in this session)*

- Summaries by each group on the findings of the previous day
- Discussion of results with emphasis on cross-area linkages and collaborative activities
- Charter for morning breakouts

Break (30 minutes)

Parallel sessions (90 minutes): Each breakout group will identify future R&D needs, prepare an assessment of opportunities in linkages to other TCP activities, and summarize potential new joint work packages between the Hydrogen, PVPS, and Wind TCPs.

Networking Lunch (60 minutes)

Plenary (60 minutes) *(Virtual Listen-Only Supported in this session)*: Each breakout group presents their findings from the previous breakout session.

Break (30 minutes)

Plenary (90 minutes): Refine conclusions from all prior breakouts as input to the TEM proceedings and discuss interest in working together on a joint task proposal. Wrap-up, next steps, Q&A.

Day 3: 8 September 2023 (Friday) – Morning

Tour (90 minutes – Pending Approval): Optional tour of the NREL Flatirons campus hydrogen and renewable energy facilities.