HYDROGEN TECHNOLOGY COLLABORATION PROGRAMME

END-OF-TERM REPORT | 2015-2020

MARCH 2020

Technology Collaboration Programme
by iea

Contents

IEA Hydrogen TCP End-of-Term Report 1 March 2015 - 29 February 2020

1.0 Introduction and Impact

As the 2015-2020 term began, the 24-Member Hydrogen Technology Collaboration Programme (Hydrogen TCP) recommitted to pursuing progress in its core business, R,D&D; expanding efforts in analysis; and intensifying outreach to build hydrogen awareness, understanding, and acceptance. During this term, the findings, lessons learned, and products derived from Hydrogen TCP (www.ieahydrogen.org) research contributed to the advancement and commercialization of hydrogen by fostering innovation, improving efficiency, and cultivating pathways to cost reduction. Toward the end of the term, the energy landscape changed. There now is a coalescing consensus about the value and potential of hydrogen that has broad commercial and policy appeal.

Moreover, just as the IEA has come to more fully appreciate the value proposition of hydrogen, the value and significance of the Hydrogen TCP to the Agency mission, vision, and Mid-Term Strategic Plan have also become clearer. Hydrogen TCP research and innovation call for a whole system approach that directly supports the IEA's evolving mandate on critical energy security. The Hydrogen TCP is committed to scale-up and industrialization, optimizing not just the hydrogen value chain but the integrated energy system to foster economic development. Production and use of hydrogen from renewable and low-carbon sources reduce emissions and improve local air quality, stimulating environmental awareness. The Hydrogen TCP strengthens the IEA energy technology network. As a global hydrogen hub with worldwide engagement—linked not only to the IEA and sister TCPs but also to external players in government and industry—the Hydrogen TCP strengthens the IEA's role as a key international hub for knowledge and expertise in clean energy.

In every respect, the Hydrogen TCP has realized its overarching 2015-2020 objective to broaden the perspective on the transformative role of hydrogen as a highly flexible energy vector and energy carrier capable of serving as a powerful tool in the global effort to combat climate change in a multi-sector energy system.

The fact that hydrogen is now positioned for market commercialization and global relevance is due in real measure to the TCP's activities and accomplishments, not just during the current term but during the prior two terms, as well. The Hydrogen TCP is already, and it is well positioned for the future. This *End of Term Report (EOT)* recounts the TCP's experience and achievements during the 2015-2020 term.

1.1 Evolving Context/Landscape - Industry and Markets

Early in the Hydrogen TCP's 2015-2020 term, a game-changer emerged in the form of low-cost renewable power. With an increasing share of renewables in the electricity mix, low-cost (USD 30/MWh) electricity from sun and wind in some areas was seen to enable the production of hydrogen at competitive cost. With the 2017 formation of the Hydrogen Council at the World Economic Forum, industry "market power" has consolidated behind hydrogen energy. Early markets for hydrogen's diverse applications showed promise. Hydrogen market trends included the following:

- 380+ **Hydrogen Refueling Stations (HRS) are** open to public or fleets worldwide; approximately 6,500 **FCEVs have been sold**;
- **Electrolysers are available** in small and large (**MW scale**) sizes;
- **Hydrogen applications are proliferating –** for industry, mobility, stationary, "**smart grid,**" **intermediates,** and **electrofuels/synfuels**
- Larger demonstrations and serious debates about "green" hydrogen and "origin" are mainstream;
- **Sector coupling and system integration are** now recognized as critical to the future energy system; and
- **Hydrogen scale-up** is a focus everywhere.

1.2 Evolving Context - World Governments

The 194 nations and European Union signatories to the 2015 Paris Climate Accord evidenced profound interest in fostering a cleaner future for present and future generations. In 2017, an IPCC Special Report named hydrogen as a model pathway for combatting climate change. As well, the Japanese Prime Minister announced Japan's intent to become the world's first "hydrogen society." The momentum for change accelerated in 2018, when hydrogen was adopted as the 8th Mission Innovation challenge and 25 EU nations united behind the "Linz Declaration" to pursue cooperative research on hydrogen. In 2019, the EU's Joint Research Center (JRC) released *The potential role of H2 production in a sustainable future power system*. As well, the first Hydrogen Ministerial Meeting in October 2018 produced the "Tokyo Statement," which was followed by Japan's voluntary contribution to the IEA for preparation of a hydrogen report to be delivered at the June 2019 G20 Meeting in Japan, the G20 President from December 2018 thru November 2019.

1.3 Evolving Context - IEA Interest in Hydrogen

In mid-2015, IEA published the *Technology Roadmap for Hydrogen and Fuel Cells,* the last in its "roadmap" series. By the beginning of 2017, the IEA Hydrogen Implementing Agreement completed its IEA-initiated rebranding as an IEA Technology Collaboration Programme (TCP). Supported by the Hydrogen TCP, the IEA held an EC workshop on electrofuels in September 2018 and included a hydrogen article in the *2018 World Energy Outlook*. Japan's voluntary contribution to the IEA supported an agency-wide effort to prepare the IEA Hydrogen Report. To kick off that effort, the IEA held a workshop in February 2019, which was attended by Chairman Paul Lucchese and General Manager (GM) Mary-Rose de Valladares. The TCP was fully engaged in the IEA Hydrogen Report process, contributing secondees to the IEA (TCP Chairman Lucchese part-time and Dutch analyst Jabbe van Leeuwen full-time), as well as GM support for the Policy and Activities Survey and ExCo Member peer review of the draft report The Clean Energy Ministerial(CEM) on hydrogen was held in May 2019; the IEA will manage this initiative on behalf of CEM. The IEA also anticipates its own permanent in-house hydrogen effort.

2.0 Strategic Framework 2015—2020

Vision
A hydrogen future based on a clean, sustainable energy supply of global proportions that plays a key role in all sectors of the economy

Mission
Accelerate H2 implementation and utilization to optimize environmental protection and improve energy security and economic development

Strategy
Facilitate, coordinate, and maintain innovative research, development, and demonstration activities through international cooperation and information exchange

2.1 Vision/Mission/Strategy

2.2 Overarching Objectives

During the 2015-2020 term, the Hydrogen TCP worked successfully towards the following overarching objectives:

Overarching Objectives

- Broaden the perspective on the transformative role of H2 by articulating and communicating its functions and value as a highly flexible energy vector and energy carrier capable of serving as a weapon against climate change in an integrated future multi-sector energy system.
- Strengthen analysis activities with a special focus on IEA analysis and publications and the competitive global energy technology environment.
- Focus on the development and implementation of the H2 infrastructure, highlighting storage, safety and cost reduction.
- Raise the profile of the HIA, enhancing its reputation for excellence in R&D and analysis, while underscoring its importance as a forum for information exchange.
- Formulate messages derived from HIA technical and analytic activities guide in order to guide and inform IEA's policy making activities.
- Foster productivity and progress through growth in membership, closer relationships and cooperation with other H2 organizations, and a broader business orientation.
- Cultivate and deepen industry participation at the task and ExCo levels.

2.3 Themes and Portfolios

Collaborative R,D&D Portfolios

- Production
- Storage
- Integrated systems
- Integration in Infrastructure

Analysis Portfolios

- Technical
- Market
- Political decision-making

Awareness, Understanding & Acceptance (AUA) Portfolios

- Information dissemination
- Safety
- Outreach

The Strategic Framework identified three themes: R,D&D; Analysis; and Hydrogen Awareness, Understanding & Acceptance (AUA). For each theme, portfolios were created to classify activities (themes and portfolios appear above).

2.4 Themes, Priorities and Portfolios

Next, the Hydrogen TCP identified priorities for each theme (and its respective portfolios) in order to guide development of the work programme and allocation of resources. The priorities for each theme appear below. All priorities supported our overarching objectives for 2015-2020. While no rank order was assigned to the priorities, all priorities for every theme were addressed during this term.

Collaborative R,D&D

THEME: COLLABORATIVE R,D &D

That advances hydrogen science and technology

PRIORITIES

1. Investigate development, deployment and delivery challenges and risks pertinent to hydrogen safety and infrastructure
2. Pursue research on hydrogen production from renewable energy
3. Explore power to hydrogen (power to gas – P2G), examining the potential for storage of intermittent renewable power sources in the natural gas grid for energy balancing
4. Continue research on solid storage of hydrogen
5. Research hydrogen production via reforming and gasification

PORTFOLIOS

- Hydrogen Production
- Hydrogen Storage
- Integrated Hydrogen Systems
- Hydrogen Integration in Existing Infrastructure

Analysis

THEME:
ANALYSIS THAT POSITIONS HYDROGEN

For technical progress and optimization For market preparation and deployment
For support in political decision-making

PRIORITIES

1. Explore the role of H2 in the energy mix of the future, assessing the maturity and state of the art of hydrogen technologies
2. Perform techno-economic and life-cycle sustainability analysis (LCSA) of H2 systems
3. Perform competitive technology and stakeholder analyses, highlighting the roles of business and innovation
4. Elaborate the interaction with IEA analysis, particularly as regards ETP and WEO activities and publications
5. Address the issue of social acceptance of hydrogen

PORTFOLIOS

- Technical
- Market
- Support for Political Decision-Making

Awareness, Understanding and Acceptance

THEME:
H_2 AWARENESS, UNDERSTANDING & ACCEPTANCE

That fosters technology diffusion and commercialization

PRIORITIES

1. Convey the state of the art and maturity of hydrogen technologies and also report on competitive and stakeholder analyses
2. Research and communicate the regulatory, code and standards (RCS) framework
3. Conduct hazard assessment and develop quantitative research assessment (QRA) tools related to safety
4. Increase the visibility and media exposure of hydrogen via IEA HIA activities
5. Influence IEA policy development through messaging derived from IEA HIA R&D and analytic activities as well as cooperation with other organizations

PORTFOLIOS

- Information Dissemination
- Safety
- Outreach

3.0 Activities and Outcomes

3.1 Tasks Operational and in Definition During 2015-2020 Term

During the 2015-2020 term, 18 tasks were in some phase of their life cycle: 12 tasks were active, and six (6) were in definition or proposed. As the term ended, five (5) tasks were current and seven (7) tasks were completed, while six (6) were in definition/proposed. Below, see the list of tasks with status and dates of operation during this term, bulleted according to the color codes of their respective themes. In addition, five (5) tasks in definition and one (1) in the proposal phase appear below in blue; there is heavy emphasis on analysis and production in these tasks.

- **Task 28 - Large-Scale Hydrogen Delivery** 2015, *Completed*
- **Task 29 - Distributed and Community Hydrogen** (DISCO-H2), *Completed*
- **Task 32 - H2-Based Energy Storage** 2015-2018, *Completed*
- **Task 33 - Local H2 Supply for Energy Applications** 2015-2017, *Completed*
- **Task 34 - BioH2 for Energy & Environment** 2015-2017, *Completed*
- **Task 35 - Renewable Hydrogen (Super Task)** *2015-2017, Completed*
- **Task 36 - Life Cycle Sustainability Assessment *(LCSA)*** *2015-2018, Completed*
- **Task 37 - Safety** 2015-2021***,*** *Current*
- **Task 38 Power-to-Hydrogen and Hydrogen to X,** 2015-2020, *Current*
- **Task 39 - Hydrogen in Marine Transport** 2016-2019, *Current*
- **Task 40 - Energy Storage and Conversion based on Hydrogen** 2019-2021, *Current*
- **Task 41c - Data and Modeling, Cooperation with ETSAP,** 2019-2021, *Current*

- **Market Deployment and Pathways to Scale,** *In Definition*
- **Biological production & conversion of H2 for energy and chemicals (Successor Task 34*),*** *In Definition*
- **Hydrogen Export Supply Chains*,*** *In Definition*
- **Hydrogen Applications In Primary Sectors (agriculture, mining and resource),** *In Definition*
- **Successor tasks for renewable electrolysis, photoelectrochemical water-splitting (PEC), and solar thermochemical hydrogen production, (STCH)** *In Definition*
- **Industrial Use of Hydrogen in Middle Income Developing countries*, In Definition***

3.2 Key Task Findings/Results, Lessons Learned & Success Stories, Products

3.2.1 R,D&D

Final reports and technology briefs are on the IEA Hydrogen website at www.ieahydrogen.org.

#	NAME, DATE	FINDINGS/RESULTS, LESSONS LEARNED & SUCCESS STORIES
	Portfolio	PRODUCTS
28	Large-Scale Hydrogen Delivery Infrastructure (2010-2013) *H2 Integration in Existing Infrastructure*	FCEVs are technically ready for market; there are no technical barriers to commercialization; no single blueprint for HRS. Market development is bottlenecked, necessitating involvement of all stakeholders.
		Final report (late 2015) - *Large-Scale Hydrogen Delivery Infrastructure-Final Report Expert Group Task 28*, Weeda and Elgowainy.
29	Distributed and Community Hydrogen (DISCO H2) (2010-2016) *Integrated H2 Systems and Analysis*	H2 would be more cost-competitive if more financial value were ascribed to environmental benefits, particularly to climate change mitigation. Homer analysis of techno-economic aspects was performed for each project. Task was seriously disrupted by loss of OA but rescued by Japan's support of new OA. Task completion is success story, as is development of Market Readiness Level (MRL) template tool.
		Final reports (2017) - *DISCO H2*, Ito; *Subtask 3 - Model Concept Development*, Ito; *Subtask 4 - Replicability and Market Readiness of the Six Case Study Technologies*, Gardiner. Created template tool for Market Readiness Levels (MRL). End-of-task workshop.
32	Hydrogen-Based Energy Storage (2013-2018) *Storage*	World's largest R&D collaboration in H2 storage: 52 experts from 17 Member countries organized in six working groups. Progress with adsorbent-based hydrogen storage; progress with Ni-MH batteries for energy storage as cheaper, safer and simpler than Li-ion batteries (in demo stage); modified Sodium hydride (NaH) shown to be reversible after four cycles. Ferroamp EnergyHub system (using Nilar Ni-MH battery packs) will enter into full-scale production, providing up to 200 kWh energy storage. Case study in efficiency of H2 storage concluded that 28,500 t molten salt could be replaced by 1,100 t MgH2 in Andasol, Spain's concentrated solar thermal energy system. Prolific publication record is success story.
		Final report - Part 1 - final public report organized by working group (in progress); **Part** 2 (special issue of *IJHE*) - Seven papers with 60 affiliations published February 2019. Special issue of *Applied Physics, A Springer* (April 2016) comprised 8 papers with 66 affiliations. Plus, Task 32 experts published >600 other publications.

33	Local H2 Supply for Energy Applications (2013-2016) *Production, Infrastructure*	80% of participants from industry; created industry electrolyser network. Cooperated with AFC TCP. **ELECTROLYZER** findings/results - Industrial alkaline and PEM electrolyser systems commercially available in containerized units (ca.10-300 Nm3/h per unit), but capital costs for pressurized water-electrolyser systems in new local supply markets require cost reduction. Reduction in stack cost (42-47% of total) expected with mass manufacturing. **REFORMER** findings/results - New generation, small-to-medium (ca. 10-300Nm3/hr per unit) reformers demonstrate flexibility in design, scale-up, and dynamics. New RE system concepts using novel reforming and CO2 capture and/or water electrolysis in development, with 75-80% overall system efficiency. **H2 supply to FCEVs** requires high purity (>99.97%H2). Existing HRS fueling protocols and H2 quality standard are strict, leading to extra costs, but do not represent technical barriers.
34	Biological Hydrogen for Energy and Environment (2014-2017) *Production*	Biohydrogen a viable prospect going forward. Will require consistent direc funding. Key drivers include not only renewable energy demand but also wast treatment, water recovery, and recovery of other valuable resources, such a phosphate. Biohydrogen production from wastes and low-grade biomasses wi be important for waste and agro-industry. Progress in both basic and applie biohydrogen production in demonstrating bioH2 production at larger scale i industrial environment. Dark fermentative hydrogen production by integratin extractive technologies is promising.
		Close to 200 publications from H2 TCP Members Proposed successor task will focus on production and conversion of hydrogen for energy and chemicals.
35	Renewable Hydrogen (2015-2017) *Production*	Combined three large and significant research areas previously organized as discrete tasks, into one super task: renewable electrolysis, photo-electrochemical production, and thermochemical production. Built network of technical experts. Collaborated with two other TCPs: AFC and SolarPACES. New world record at NREL – 16% solar to H2 efficiency in PEC water splitting; high-efficiency III-V semiconductors from Germany; and US achievement of 14% solar-to-H2 efficiency in PEC water splitting.
		Final Report - Task 35: *Renewable Hydrogen Production.* Innovative structure created international network to monitor research.
39	Hydrogen in Marine Applications (2017-2019) *Infrastructure*	Built maritime industry platform - vessels and ports; building "know-how" for sector that is primary means of transportation worldwide (responsible for 90% of all inter-country trade). Supporting development of regulatory framework for hydrogen in the maritime industry.
		Three white papers in progress: 1) "Realizing H2 in the maritime - experience and knowledge gaps;" 2) H2 safety, regulations, codes & standards;" 3) "H2 logistics and ports."
40	Energy Storage and Conversion Based on H2 (2019-2021) *Storage*	Eight working groups, including new working group on ammonia and reversible liquid carriers.
		IEA H2 TCP sponsorship of MH Gordon conference.

3.2.2 Analysis

The "analytic imperative"— the need for rigorous, independent analysis that supports collaborative R&D efforts and addresses the bigger picture for hydrogen — was first discussed in the *2009-2015 Strategic Plan*, and it continued to drive the Hydrogen TCP's analytic activities during the 2015-2020 term. In October 2017, during the early stage of IEA restructuring, Hydrogen TCP analysts and IEA analysts met at headquarters to coordinate with IEA on ETP and other analysis efforts. Two years later, in 2019, the IEA held a workshop on hydrogen for the global hydrogen community, in preparation for development of the IEA Hydrogen Report.

#	NAME, DATE	FINDINGS/RESULTS, LESSONS LEARNED & SUCCESS STORIES
	Portfolio	PRODUCTS
36	Life Cycle Sustainability Analysis (LCSA) 2015-2018	Developed life-cycle costing framework. LCSA is a convenient methodological solution to evaluate the performance of H2 energy systems. LCSA concludes that different calculations associated with conventional LCC, as well as LCC with externalities, influence levelized cost of H2.
		Final report - *Task 36: Life Cycle Sustainability Assessment of Hydrogen Energy Systems.*
38	Power-to-Hydrogen and Hydrogen-to-X 2016-2020	Provided comprehensive assessment of various technical and economic pathways to Power-to-H2 applications in diverse situations as well as the existing legal frameworks. Performed extensive data collection and analysis on techno-economic studies and business cases as well as PtX demonstrations. Regularly held workshops on demonstrations, in conjunction with meetings. Organized WHEC2018 round table "The Role of Hydrogen in Energy Policies" and participated in other WHEC2018 and non-hydrogen conferences. Collaborating with ETSAP project, Task 41c.
		Three technology briefs: 1) "Electrolysis: what are the investment costs?" 2) "Incentives and Legal Barriers;" 3) "Services to the Grid." Produced several journal articles: "Task Force Electrolyser Data," Proost *(IJHE);* "Energy System Models and Hydrogen," *(Nature Energy);* "Task 38," *Research Gate.* Three (3) databases: demonstrations; techno-economic analyses; and national legislation.
41 c	Data and Modeling 2020-2023	Subtask 41c – Cooperation with ETSAP (via ETSAP project) – underway. Project aims to better understand and improve modeling of hydrogen, especially within IEA and the IEA network. It is also intended to inform other Task 41 subtasks, providing a sustainable data validation system and enhanced approach to hydrogen modeling. Longer term ambition is to incorporate database as Secretariat function.

3.2.3 Awareness, Understanding and Acceptance (AUA)

The AUA theme encompassed the Safety portfolio (and its Safety task) as well as the information dissemination and outreach portfolios.

NAME, DATE	**FINDINGS/RESULTS, LESSONS LEARNED AND SUCCESS STORIES**
Portfolio	PRODUCTS
Safety 2015-2021	Provided structural and quantitative contributions, including testbed, to HyRam quantitative risk assessment (QRA) platform in dedicated subtask. Held European workshop back-to- back with ICHS. Supported Sponsor Member HySafe on ICHS conferences. Launched *Hydrogen Safety Journal*.
	HyRam QRA tool kit; *Hydrogen Safety Journal*; 2 joint publications in peer-reviewed journal, *Process Safety and Environmental Protection.*

3.3 Information Dissemination and Outreach

The Hydrogen TCP produced the following materials, all of which may be found on the website at www.ieahydrogen.org: Annual Reports (redesigned in 2016); *IEA H2 News* newsletters (periodic); press releases; and a regularly updated Executive Summary. In 2017, at the request of the Executive Committee (ExCo), the GM developed a special report, *Global Trends and Outlook for Hydrogen,* to inform policy and decision-makers about the status of hydrogen technologies. During this term, the Hydrogen TCP expanded its marketing channels by building a robust social media presence on Twitter (@IEA_Hydrogen) and Facebook. TCP Twitter alone has more than 2,800 followers.

External conferences and event outreach at the ExCo and Secretariat level bore fruit. At conferences and events of community-wide stature, sixteen (16) presentations were delivered by the Chairmen, Vice-Chairmen and/or GM on behalf of the ExCo; twenty-five (25) presentations on task topics were delivered by Operating Agents (OAs) and experts. The GM attended the 2016 Bonn Conference of the United Nations Framework Convention on Climate Change (UNFCCC) by UNFCCC invitation. At the 2016 UNFCCCC COP in Morocco, the Hydrogen TCP also participated in a joint event with the Campaign for a Hydrogen Economy, a registered UK charity. The UNFCCC produced a hydrogen video interview with the GM at COP 2016. There were two conference exhibits, one at the COP and another at World Hydrogen Technology Convention (WHTC). At WHEC 2018 in Rio, a keynote roundtable moderated by Chairman Lucchese featured five (5) TCP experts. As well, a global hydrogen awareness event moderated by Vice-Chair Dr. Jonathan Leaver was held at a strategic venue in Auckland, New Zealand. These last two events produced a combined total of 18 presentations. An internal awareness building event was held in the UK. The Hydrogen TCP co-sponsored the 2015 and 2017 International Conferences on Hydrogen Safety (ICHS), as well as the 2019 Hydrogen-Metal Systems Gordon Research Conference, providing financial, technical and marketing support for these events.

At the task level, there were over 930 presentations, and 960 publications in journals and publishing services as well as conference proceedings. There were 58 task meetings and some 40 topical workshops, including three Task 38 workshops organized after plenary task meetings in Tokyo, Japan (February 2018), Aix en Provence (November 2018) and Puertollano, Spain (September 2019). In addition, there were three (3) End-of-Task workshops for Task 28 (Infrastructure), Task 33 (Local H2 Supply for Energy Applications), and Task 37-19/31 (Safety) that delivered a combined total of more than 50 presentations. These workshops were held, respectively, in the Netherlands, Norway and Japan.

4.0 Participation, Labor and Product Development

Altogether, some 365 experts participated in Hydrogen TCP tasks during this term: 77 (21%) from government, 198 (54%) from research institutions/academe (often government related), and 90 (25%) from industry. Since the Hydrogen TCP is task-shared, labor is accounted for in person years. Labor contribution for approved tasks (excluding tasks in definition) was conservatively estimated at 420 person years.

Loss of key experts (especially OAs or Subtask Leaders) through job change, retirement, or member withdrawal has slowed the completion of tasks and delivery of reports. Lower than anticipated OA funding has also reduced participation in some cases. Despite these challenges, the Hydrogen TCP has been resilient, identifying new experts to lead tasks and complete reports while developing successor tasks.

While increased industry participation has enriched IEA Hydrogen activities, industry participants are often not in a position to contribute substantially to writing final reports and other key task products. Such crucial, labor-intensive activities are more often performed by experts from institutes and academe. This situation affects high industry-participation tasks, in particular. Consequently, the Introduction of technology briefs (suggested by CERT Chair Dr. Mignone) has proven to be an excellent innovation. The TCP has implemented this approach and is requiring briefs from all new tasks, thereby optimizing task resources and facilitating access to data on task results.

5.0 Membership, Governance and Resources

5.1 Membership

At the beginning of the term, there were 24 members of the Hydrogen TCP; by the end of the term, there were 31, marking a 29% net gain in approved membership (**See Appendix 1, Hydrogen TCP Members**). During the term, the Hydrogen TCP welcomed seven new members: five Contracting Party members and four Sponsors. There were two withdrawals: one Contracting Party member and one Sponsor member. As the term closed, the Hydrogen TCP had 25 Contracting Parties and 6 Sponsor Members.

The accession of new members has been invigorating. China completed its protracted accession process, with two concomitant Contracting Parties. New Contracting Party Belgium has strong hydrogen activities; Contracting Party Austria has a commitment to hydrogen at a national level. Contracting Party Canada, a prime mover in the hydrogen space, returned to the Hydrogen TCP in late 2019, ensuring North American representation. Portugal, a global leader in renewable energy, also joined as a Contracting Party. Argentina remains in accession.

New Sponsor Member Southern Company, a combined U.S. gas and electric utility, is our first utility. The Hydrogen Council, a new Sponsor Member, brings the market power of industry to TCP research and innovation. New Sponsor Reliance Industries Limited (RIL) is the Hydrogen TCP's first Member from India. Sponsor Hychico is our first Member from Latin America.

The United States withdrew as a Contracting Party and HySafe withdrew as a Sponsor. In response to the U.S. letter of withdrawal, four Hydrogen TCP chairmen (three past and the incumbent Lucchese) responded in a letter clarifying the apparent U.S. misconceptions about topics including the TCP legal framework, advocacy and outreach, and IT, as well as transparency and oversight. HySafe withdrew because its funding structure had contracted significantly. However, an underlying Memorandum of Understanding (MOU) remains in effect, allowing for cooperation between the Hydrogen TCP and HySafe.

The reengagement of Contracting Party UNIDO is especially noteworthy, because it has opened doors to the developing world, particularly in the industrial context. Recruiting efforts have produced serious expressions of interest in the Hydrogen TCP membership from Slovakia, Singapore, South Africa and Thailand. Outreach to Mexico, Brazil, Morocco, California, and Enbridge has also taken place.

5.2 Governance and Resources

The ExCo elects a chairman and two vice-chairs every three years. Two chairmen served during this term: Stefan Oberholzer of Switzerland (June 2014-2017) and Paul Lucchese of France (June 2017-June 2020). Vice-chairs Eric Miller of the U.S. and Yong Gun Shul of Korea were elected and served with Stefan Oberholzer. Vice-chairs Eiji Ohira of Japan and Jonathan Leaver of New Zealand were elected and serve with Paul Lucchese.

Notwithstanding the Hydrogen TCP's growth in membership, the ExCo has continued to budget conservatively. This practice dates to 2014, the last time the Common Fund Dues were increased. That increase was intended not only to cover current expenses but to facilitate creation of a reserve for use in case of emergency or opportunity. The Hydrogen TCP has built up a modest financial reserve.

Budget authority is passed every year. Relative to oversight, IEA Hydrogen has a biennial financial review by an independent Certified Public Accountant; this procedure has been in place since June 2005. The Hydrogen TCP's financial accounting and statement preparation conforms with Generally Accepted Accounting Principles (GAAP), as required by the Hydrogen TCP's Implementing Agreement (referred to internally as the "Legal Text"). Two financial reviews took place during this term, in 2017 and 2019.

In addition to its Implementing Agreement (Legal Text), the Hydrogen TCP has had a *Handbook of Policies and Procedures* in place since 2002.[1]

Since 2012, due to U.S. concerns about travel costs, the Hydrogen TCP had arranged its ExCo Meeting schedule as follows: two in-person ExCo Meetings in odd years; one in-person and one online ExCo Meeting in even years. With the U.S. withdrawal from the Hydrogen TCP in June 2018, the ExCo Meeting schedule was planned to revert to two in-person ExCo Meetings per year, accommodating growth in business. However, in 2018, there were three in-person ExCo Meetings, followed in rapid succession by another in-person ExCo Meeting in early 2019. The number and timing of these meetings was driven by various factors including the strategic planning process as well as and the timing and location of a key conference to which the Hydrogen TCP had already committed. A return to two ExCo Meetings/year is anticipated, coupled with an option for remote participation.

6.0 Impact and Relevance of the Hydrogen TCP on IEA and within the TCP Network

On behalf of the ExCo, the Chairman or GM (occasionally both as needed and appropriate) participated in the following meetings: a 2018 CERT transport focus meeting; 9 REWP meetings; 5 EUWP Transport Contact Group meetings; three (3) TCP Universal meetings; and a joint analysis meeting in 2017. In addition, ExCo member Dr. Eli Varkaraki and Shell Germany CEO Stijn van Els participated in two different OECD Transport Forums on behalf of the Hydrogen TCP. The Hydrogen TCP cooperated with the IEA Climate Change Division to attend UNFCCC events.

The ExCo (as well as OAs and experts, when invited) reviewed IEA documents on a regular basis. The Hydrogen TCP contributed throughout development of the *Technology Roadmap for Hydrogen and Fuel Cells*. The TCP contributed to peer reviews of the 2015, 2016 and 2017 issues of *Energy Technology Perspectives* as well as the 2017 *Medium-Term Renewable Energy Market Report (MTRMR).* In 2018, the TCP was pleased to provide material for a Mission Innovation presentation by the CERT Chair at her request. In

[1] **Note**: the Hydrogen TCP's *Handbook* predates the IEA Secretariat's 2014 *Handbook* by 12 years.

early 2019, the Chairman was seconded part-time to the IEA for several months to advise on preparation of the *IEA Hydrogen Report.* The Hydrogen TCP also provided advice and information on policy analysis and activities for this report and the ExCo commented on the draft report.

At the 2018 World Hydrogen Energy Conference, the Chairman held a keynote round table on "Scenario Analysis at the IEA and Beyond." The Hydrogen TCP also played a central role in producing the September 2018 IEA/EU comprehensive electrofuels workshop, where the Chairman delivered the Hydrogen TCP presentation on hydrogen as a building block of electrofuels. By invitation, the Chairman and GM attended the IEA Hydrogen Workshop in February 2019. In November 2018 and April 2019, the Chairman attended the IEA Energy Business Council.

At the ExCo level, the Chairman attended a meeting and workshop hosted by the Combustion TCP. At the task level, important cooperation with other TCPs took place. The Advanced Fuel Cells (AFC) TCP cooperated with Task 33 (Local H2 Supply for Energy Applications). The Solar PACES TCP participated in Subtask 3 (Solar-Thermochemical Water-Splitting) of Task 35 (Renewable Hydrogen Production). Task 41c is a collaboration-and-analysis Subtask with an ETSAP project. The GM contributed case studies—one in collaboration with the Task 33 (DISCO H2) OA Dr. Federico Villatico-Campbell—to two RETD TCP tasks. In November 2019, the GM co-organized and also presented at a hugely successful workshop on Hydrogen Production with CCS that was produced by the CSLF, IEAGHG, Equinor and IEA Hydrogen; this workshop is expected to serve as a model for future IEA Hydrogen collaboration with other TCPS and interested organizations.

Appendix 1 – List of Hydrogen TCP Members

MEMBER COUNTRY/ INTERNATIONAL ORGANIZATION	CONTRACTING PARTY	YEAR OF ACCESSION	YEAR OF WITHDRAWL	TYPE
Australia	Commonwealth Scientific and Industrial Research Organization (CSIRO)	2005	N/A	G
Austria	Federal Ministry of Transport, Innovation and Technology	2018	N/A	G
Belgium	Waterstof Universite Catholique de Louvain Division of Materials and Process Engineering	2015	N/A	I R
Canada	Natural Resources Canada	1977; 2019	2013	G
China	Dalian Institute of Chemical Physics, Chinese Academy of Sciences Division head of hydrogen energy and advanced materials Dalian Instititute of Chemical Physics	2016	N/A	R
Denmark	Danish Energy Authority	2004	N/A	G
European Commission	European Commission, DG JRC	1977	N/A	R
Finland	Finnish Funding Agency for Technology and Innovation (TEKES)	2006	N/A	G
France	Commissariat à l'énergie atomique et aux énergies alternatives (CEA)	2004	N/A	R
Germany	Institution of Energy Research, Forschungszentrum Jülich GmbH	1977~1999, 2007	N/A	R
Greece	Centre for Renewable Energy Sources (RES) & Hydrogen Technologies	2006	N/A	R
Iceland	National Energy Authority	2003	2013	G
Israel	Ministry of Energy and Water Resources	2012	N/A	G
Italy	ENEA IDROCOMB Casaccia Research Center	1977	N/A	G
Japan	The New Energy and Industrial Technology Development Organization (NEDO)	1977	N/A	G

Korea	Ministry of Trade, Industry and Energy, MOTIE (formerly known as Ministry of Commerce, Industry and Energy, MOCIE)	2005	N/A	G
Lithuania	Lithuanian Energy Institute	2002	N/A	R
New Zealand	Ministry of Business Innovation and Employment	2005	N/A	A
Norway	The Research Council of Norway	1994	N/A	G
Portugal	Directorate General of Energy and Geology	2019	N/A	G
Spain	Instituto Nacional De Técnica Aeroespacial (INTA)	1996	N/A	G
Sweden	Swedish Energy Agency	1977	N/A	G
Switzerland	Swiss Federal Office of Energy	1977	N/A	G
The Netherlands	Netherlands Enterprise Agency	1977	N/A	G
Turkey	TUBITAK Marmara Research Center Energy Institute	1995-1996, 2007	2013	R
UNIDO	United Nations Industrial Development Organization	2009	N/A	G
UK	Department of Energy & Climate Change	1979-1998, 2002	N/A	G
USA	Department of Energy	1977	2018	G

SPONSOR MEMBER		YEAR OF ACCESSION	YEAR OF WITHDRAWL	TYPE
Hychico	Hychico S.A.	2018	N/A	A
Hydrogen Council	Hydrogen Council	2018	N/A	A
HySafe	HySafe	2013	2017	I
Nationale Organisation Wasserstoff- und Brennstoffzellen technologie GmbH	NOW GmbH	2013	N/A	P
RIL	Reliance Industries Limited (RIL)	2018	N/A	I
Shell Global Solutions International BV	Shell	20133	N/A	I

G: Government **R**: Research Institute **I**: Industry **P**: Public-private partnership **A**: Association