United Nations ECE/ENERGY/2021/20

Economic and Social Council

Distr.: General
15 September 2021

English only

Economic Commission for Europe

Committee on Sustainable Energy

Thirtieth session
Geneva, 22-24 September 2021
Item 7 of the provisional agenda
Future work of the Committee on Sustainable Energy

Attaining carbon neutrality - The role of hydrogen

Focus on Guarantees of Origin

Note by the Secretariat

I. Introduction

1. The potential role of Guarantees of Origin (GO) in attaining carbon neutrality is proposed to be illustrated by development of a Guarantee of Origin for hydrogen (GOH). A GOH, as outlined below, should not be treated as a stand-alone instrument, used to record and track different batches of hydrogen produced from various sources or technologies (these often are referred to as green, blue, yellow, or brown hydrogen). Rather, to harness its full potential, a GOH should be a part of a comprehensive portfolio of Guarantees of Origin (GOs) developed for all energy carriers reflecting a life cycle analysis (LCA), used to calculate their carbon footprints. Recognizing that development of a full-fledged framework of GOs for various energy carriers will require extensive preparation, the debate and development of a GOH in a first instance would be a model for development of a comprehensive structure for GOs for all energy carriers in the context of a dynamic resource management system such as the United Nations Resource Management System.

2. At the twenty-ninth session of the Committee on Sustainable Energy (Geneva, 25-27 November 2020), the Group of Experts on Gas presented the document "Hydrogen – an innovative solution to carbon neutrality" (ECE/ENERGY/2020/8[1]). The document offered several options available to United Nations Economic Commission for Europe's (ECE) member States, the energy industry, and financial institutions as they strive to accelerate decarbonization by harnessing hydrogen.

3. A workshop on "Attaining Carbon Neutrality: The Role of Hydrogen"[2] was organized on 24 March 2021 as part of the project "Enhancing understanding of the implications and opportunities of moving to carbon neutrality in the UNECE region across the power and energy intensive industries by 2050". The workshop stressed the role of hydrogen in

[1] United Nations Economic Commission for Europe – UNECE. (2020). Hydrogen – an innovative solution to carbon neutrality. Note by the Group of Experts on Gas. Retrieved from https://unece.org/sites/default/files/2021-03/ECE_ENERGY_2020_8_Hydrogen_final.pdf.

[2] https://unece.org/info/Sustainable-Energy/Natural-Gas/events/354150.

achieving carbon neutrality by recommending design and implementation of supportive mechanisms such as a Guarantee of Origin across ECE sub-regions that would address an initial green premium and subsequently, support further cost reductions for hydrogen projects through experience and scale effects. It is recognized that hydrogen is one of many gases (for example, renewable methane, bioenergy with carbon capture and storage, and so forth) that will be expected to contribute to achieving carbon neutrality.

4. Endorsing the key recommendations of the document on hydrogen, the Committee encouraged ECE member States to collaborate on adopting a uniform methodology for calculating life cycle greenhouse gas (GHG) emissions from all energy carriers, beginning with hydrogen, and on developing comprehensive and science-based terminology, as well as standards or best practices for its deployment. The Committee invited ECE member States to expand collaboration on sustainable hydrogen production across the ECE region and called for the development of a sustainable hydrogen market by developing market stimulation programmes. As comparable instruments are developed for other gases they would be expected to contribute to a growing market for decarbonized gases.

5. At its eighth session, 25-26 March 2021, the Group of Experts on Gas built upon the Committee's conclusions and recommendations concerning hydrogen development in the ECE region. The Group Experts on Gas agreed that all technological and financial options for hydrogen production, transmission, storage, and use should be considered agnostically and discussed from a level playing field perspective. The Group of Experts on Gas concluded that retrofitting and repurposing existing natural gas infrastructure could accelerate the transition to a future hydrogen ecosystem in a cost-effective way. It is noted that the existing natural gas infrastructure would be able to support a wide spectrum of decarbonized gases.

6. Stressing the importance of operationalizing the recommendations outlined in ECE/ENERGY/2020/8, the Group of Experts on Gas at its eighth session[3] recommended to:

(a) Agree on a comprehensive and science-based terminology for renewable, and low-carbon and decarbonized gases, beginning with hydrogen, and to use the agreed terminology to adapt national legal definitions, provide a clear taxonomy, and foster collaboration and investment flows;

(b) Develop a tradeable Guarantee of Origin for Hydrogen to decouple physical from commercial flows and thereby accelerate hydrogen deployment. The Group of Experts offered its assistance to member States in developing GO or similar mechanisms.

7. With the foregoing recommendations in mind, the Group of Experts on Gas concluded that, when comparing different energy vectors and constructing different GOs, it will be necessary to assess their environmental impacts along their entire value chains. A comparable lifecycle analysis (LCA) "from cradle to grave" would be the foundation of a Guarantee of Origin (GO) system to be used for all energy carriers. As part of liquid, transparent, and robust energy markets in a context of sustainability, it is essential to establish a unique but comprehensive GO system for all energy carriers, including electricity and gases. In this regard, an eventual GO system should feature information on the environment, social, and economic impact of energy carriers, allowing producers and consumers to make informed choices about the options to decarbonize the system. Such information would raise consumers' awareness and accelerate decarbonization by incentivizing demand. Linking sustainability information and GHG emissions/savings with all types of GOs based on a LCA for all energy carriers would ease the market functioning by preventing double disclosure and false claims though GOs and other similar certificates.

[3] UNECE. (2021). Eighth session. Report of the Group of Experts on Gas. Retrieved from https://unece.org/sites/default/files/2021-04/ECE_ENERGY_GE.8_2021_2_Final.pdf.

II. Guarantee of Origin: its origin, scope, and benefits

8. The Guarantee of Origin mechanism was introduced in 2001 by the European Directive 2001/77/EC to give better visibility to producers of renewable electricity[4]. According to the Renewable Energy Directive 2018/2001/EU, the GO-EU is defined as a tracking instrument that labels renewable electricity, gas and heat and provides information regarding its energy sources[5]. A transferable (tradable) electronic "stamp of approval" GO enables a uniform cross-border scheme to facilitate sustainable energy production throughout the region. When purchasing the GO, a customer does not need to buy energy from the GO seller to claim the positive externalities of the source that the GO represents.

9. The development of the European GO market shows promise. GO volumes in the European Economic Area (EEA) experienced steady growth throughout the past decade. It is particularly important to highlight a 10.8 per cent yearly increase in canceled GO (issued between 2009 and 2018)[6], which indicates that the growth concerns both GO supply and demand. Similar trends have been observed in other regions that have implemented low-carbon energy certification[7].

10. There is no consensus on whether or how GO could apply to hydrogen decarbonization. When first introduced by the EU Directive, the GO scope did not include hydrogen explicitly. The original GO scheme applied to renewable energy sources: wind, solar, aerothermal, geothermal, hydrothermal, ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas, and biogases. In 2018, the EU reviewed the GO definition to cover non-renewable sources: "This [scope extension] would provide a consistent means of proving to final customers the origin of renewable gas such as biomethane and would facilitate greater cross-border trade in such gas"[8]. It was specifically highlighted that the revisited definition could allow for the introduction of guarantees of origin for hydrogen – under "another renewable gas"[9]. At the same time, the updated definition recognized non-renewables as of second-tier priority. The jurisdiction of a possible future GO is limited to the national level: "Extending the guarantees of origin system to energy from non-renewable sources should be an option for the Member States"[10].

III. Guarantee of Origin for Hydrogen (a model for GOs for all energy carriers)

11. Recent exchanges reveal that similar views exist among ECE stakeholders. Since its first official reference at the twenty-ninth session of the Committee on Sustainable Energy[11], a GOH has featured in Committee discussions. The interest in hydrogen continues to grow and stakeholders urge adoption of market policies like GOH to facilitate a hydrogen market[12].

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[4] European Commission – EC. (2001). Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32001L0077&from=FR.

[5] EC. (2009). Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. Retrieved from https://eur-lex.europa.eu/eli/dir/2009/28/oj.

[6] Jimmy, N. (2020). An Overview of the Development of the Guarantee of Origin Market. Retrieved from https://www.researchgate.net/publication/341548253_An_Overview_of_the_Development_of_the_Guarantee_of_Origin_Market?enrichId=rgreq-a774be470a83c11c68bdecb026740416-XXX&enrichSource=Y292ZXJQYWdlOzM0MTU0ODI1MztBUzo4OTM2MTE0NzQ0MzYwOThAMTU5MDA2NDk4NjQ5OQ%3D%3D&el=1_x_3&_esc=publicationCoverPdf.

[7] See, e.g., Hasegawa, M. (2020). Japan boosts FiT energy certificate trades. Retrieved from https://www.argusmedia.com/en/news/2160120-japan-boosts-fit-energy-certificate-trades.

[8] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001&from=EN.

[9] See EC 2018/2001, p. 59.

[10] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.328.01.0082.01.ENG&toc=OJ:L:2018:328:TOC.

[11] UNECE. (2020). Hydrogen – an innovative solution to carbon neutrality.

[12] UNECE. (2021). Workshop-Attaining Carbon Neutrality: The Role of Hydrogen. Retrieved from https://unece.org/sustainable-energy/events/workshop-attaining-carbon-neutrality-role-hydrogen.

12. The ECE community envisages GOH as an instrument to be applied as well to renewable, low-carbon and decarbonized sources. At its eighth session, the Group of Experts on Gas reiterated the need to design and implement support mechanisms such as Guarantees of Origin for hydrogen as part of a broader interrelated GOs system developed for all energy carriers, across ECE sub-regions that would provide an initial green premium until experience and scale effects reduce the costs of sustainable hydrogen projects. The statement was backed by the conclusions of a recent ECE hydrogen workshop – the event attracted hundreds of stakeholders from business, the public sector, and academia[13].

13. At its eighth session the Group of Experts on Gas reiterated the need to develop a standard for renewable and low-carbon hydrogen. The intention was to use this framework for adapting national legal definitions and offering a clear taxonomy that would "provide legal certainty and foster collaboration and investment flows"[14]. The taxonomy would take in account current and discussed legislation in the European Union framework and other ECE sub-regions.

14. GOH labeling is essential to achieve meaningful decarbonization results in a hydrogen blending scenario[15]. For countries with existing gas infrastructure, the most cost-effective solution to develop a hydrogen ecosystem at scale is by adapting existing pipelines and storage facilities to hydrogen. Increasing hydrogen concentrations in the natural gas mixture is a first feasible step in this undertaking.

15. On the other hand, hydrogen transported through pipelines faces similar technical challenges to energy infrastructure decarbonization as does renewable electricity delivered through the grid. Once injected, hydrogen, sustainable or not, will be transported through the pipe network with no feasible way to distinguish its environmental properties. GOH certification at the moment of production could serve as a proxy to renewable, low-carbon, or decarbonized credentials of a hydrogen batch and derived products. GOH certification issued by a qualified manufacturer allows GOH buyers to claim its climate benefits while consuming hydrogen delivered in the mix.

16. The ECE Group of Experts on Gas expressed its readiness to support establishment of a common, ECE-wide model for hydrogen certification[16]. The reasons for such keen interest in a GO for hydrogen lie in the distinctive advantages of this instrument:

(a) *GOH could assume the benefits of environmental labeling (EL).* Because of the specific attributes of hydrogen and its distribution options, it is impossible to distinguish how it was produced. A reliable way to make hydrogen sources traceable is to mark them at the production stage. A GOH scheme certifies both hydrogen manufacturers and hydrogen batches. The GOH rules could provide that qualified hydrogen producers can issue GOH with a supporting label marking hydrogen as renewable, low-carbon, or decarbonized. Anybody acquiring GOH certificates/or GOH-certified hydrogen would be assured that they are consuming sustainable energy. Moreover, the GOH buyers could also use the GOH label for marketing purposes. Given that in recent decades "eco-friendly" products have been in greater demand, the environmental labeling feature of GOH seems to be most timely. GOH labeling can justify higher prices for qualified hydrogen and its derived goods – without such labelling the latter would be obliged to assume the costs of externalities (CO_2 emissions). Price increments, or "green premia", and the opportunity to diversify are two ultimate functions of environmental certificates: in the GOH case, they secure the financial viability of renewable/low-carbon/decarbonized hydrogen projects;

(b) *GOH can attract responsible financing.* In theory, nothing should restrict interested parties from buying GOH certificates. Neither actors purchasing hydrogen for

[13] UNECE. (2021). Hydrogen – pipe dream or quickest path to carbon neutrality? Retrieved from https://unece.org/climate-change/news/hydrogen-pipe-dream-or-quickest-path-carbon-neutrality.

[14] UNECE. (2021). Eighth session. Report of the Group of Experts on Gas. Retrieved from https://unece.org/sites/default/files/2021-04/ECE_ENERGY_GE.8_2021_2_Final.pdf.

[15] Different member States have different views on "hydrogen blending". Some support the use of hydrogen only in those areas that cannot be directly decarbonized electrically. Blending may blur these boundaries.

[16] Certification for hydrogen could serve as a model for GOs for other energy carriers.

production purposes nor final customers conclude the list of market participants. The opportunity to sell GO to anyone opens the hydrogen market to corporate social responsibility-oriented investments. In other words, the GO scheme gives more options for raising funds for renewable, low-carbon and decarbonized hydrogen production projects. Earnings from selling GOH could go to activities on renewable /low-carbon hydrogen production or for maintaining/improving the environmental credentials of the GOH issuer;

(c) *GOH facilitates (international) trade in two key aspects.* First, GO is an electronic document so **physical hydrogen supply can be decoupled from its carbon properties**. A company acquiring GO does not need to purchase the hydrogen from the same GO issuer to claim its environmental benefits. An enterprise in Budapest (Hungary) could buy GOH from a hydrogen plant in Vladivostok (Russian Federation) and the corresponding volume of *physical* hydrogen from a manufacturer nearby. This transaction would be considered as purchasing renewable/low-carbon/decarbonized hydrogen even if the closest producer is not GOH-certified. The GOH scheme enables cross-border trade in sustainable hydrogen regardless of its geographical location. Secondly, if made into a binding regulation, GOH certification will be among the determining factors for the size of a carbon border mechanism and similar environmental levy. This assumes that the scheme is based on a **harmonized international framework** (agreed basic definitions, verification procedures, etc.). ECE as a body with extensive geography and proven experience in developing norms and standards and fostering dialogue and cooperation is at a vantage point to deliver on this task;

(d) *GOH fosters carbon transparency and knowledge dissemination.* GO aims to inform and educate the community and consumers about the different origins and environmental properties of hydrogen. In addition, the data collected through the GO registry may (upon permission) be used for research and forecast; it could also be applied for performance-based targets/standards-setting. In a consolidated manner, the data from the GO database[17] could be used to raise awareness about the environmental impact of a taken sector. Finally, the information may help market players to measure and strengthen their carbon credentials; this data could be included in their sustainability reports to show compliance with the tightening environmental regulation.

17. As of today, GOH and similar certifications are present/under development in multiple geographies. Among others, schemes are established for the EU (GOH) and its Member States (GOH)[18], as well as for Australian (GOH)[19] and Japanese (non-fossil fuel value[20] and green energy certificates[21], local low-carbon hydrogen schemes[22]) markets.

[17] GOH Database – an electronic registry collecting information about GOH issued and cancelled.

[18] See, e.g., Legifrance. (2021). Ordonnance n° 2021-167 du 17 février 2021 relative à l'hydrogène. Retrieved from https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000043148001.

[19] See, e.g., Out-law News. (2020). Australian body launches renewable hydrogen certification scheme. Retrieved from https://www.pinsentmasons.com/out-law/news/australian-body-launches-renewable-hydrogen-certification-scheme.

[20] See, e.g., CMS Legal Services. (n.d.). Current state of hydrogen projects in Japan. Retrieved from https://cms.law/en/int/expert-guides/cms-expert-guide-to-hydrogen/japan; Ministry of Economy, Trade, and Industry – METI, Japan. (2019). Non-fossil Fuel Energy Certificates with Tracking Information to be Sold Utilizing the FY2019 First Auction for Non-Fossil Fuel Energy Certificates. Retrieved from https://www.meti.go.jp/english/press/2019/0701_003.html.

[21] Ministry of Economy, Trade, and Industry – METI, Japan. (2017). CO2-Free Hydrogen Working Group-Report. Retrieved from https://www.meti.go.jp/report/whitepaper/data/20170307001.html; For more information about Green Certification in Japan. See the Institute of Energy Economics, Japan. (2008). Overview of the Green power Certification System. Retrieved from https://eneken.ieej.or.jp/en/data/pdf/493.pdf.

[22] Aichi Prefectural Government (2018). Low carbon hydrogen certification system. Retrieved from https://www.pref.aichi.jp/soshiki/ondanka/low-carbon-hydrogen.html.

III. Adopting a Guarantee of Origin for Hydrogen in the ECE region

18. The Report of the twenty-ninth session of the Committee of Sustainable Energy[23] highlights the importance of the **science-based approach** when qualifying hydrogen properties. For future hydrogen taxonomy that means a requirement to use objective and scientifically derived criteria, indicators, and methodologies. Again, distinguishing hydrogen production based on its carbon intensity is more rigorous, from a scientific point of view.

19. The Committee also provided some baseline orientations for defining renewable and low-carbon hydrogen. Renewable hydrogen was described as produced from renewable energy sources, such as wind and solar with a carbon footprint being close to zero. Low-carbon hydrogen is explained as manufactured from other technologies, such as fossil fuels (natural gas or coal) with carbon capture, use and storage (CCUS), whereas the carbon footprint is relatively low[24].

20. Taking the above in account it is clear that the launching of an ECE region-wide GOH requires extensive groundwork. Developing a reference standard and resolving cost-efficiency are among the key challenges. In addition, as a tradable, traceable, and transparent certificate, GOH depends on procedures ensuring smooth exchanges between issuers and buyers. If ECE were to play a role in establishing GO for hydrogen, it could address the following core questions:

21. **"WHAT"** defines hydrogen environmental quality. ECE should agree on reference qualifications for renewable and low-carbon hydrogen; on applicability and interpretation of related categories (decarbonized, zero-carbon, or clean hydrogen); and on a standardized method for measuring the carbon intensity of hydrogen manufacturing.

22. **"HOW"** can the environmental quality of hydrogen be judged. ECE could examine existing conformity assessment schemes for hydrogen and other energy production. It then could identify best practices, challenges, and gaps – any input that may help to design an efficient standard procedure for tradable hydrogen certification. This model instrument could be applicable throughout the ECE region. To the point feasible, the GOH assessment could cover the whole hydrogen life cycle, not just the immediate production stage.

23. The establishment of baseline quantifiable thresholds for renewable, low-carbon, and decarbonized hydrogen has numerous practical implications. Inter alia, it is a prerequisite for developing a working international hydrogen certification scheme like the Guarantee of Origin.

24. Today a wide range of hydrogen production methods is technically feasible; all have different costs and carbon burdens. In the absence of specific emission taxing, emission-intensive hydrogen is generally cheaper than one with low CO_2 emissions. If nothing changes, emissions from "dirty" hydrogen production will emit significant GHG volumes by 2050. Low-carbon hydrogen manufacturing will have a minor effect if no new technologies emerge. In a context of energy decarbonization, these trends indicate a need for policies promoting renewable and low carbon hydrogen production such as GO. To foster renewable, low-carbon, or decarbonized hydrogen the stakeholders first need to agree on a standard definition to this category. This definition should operate on metrics that enable comparability of hydrogen production methods. Calculating and measuring carbon footprint against a threshold could be a relevant approach.

25. When developing a standard vocabulary for renewable and low-carbon hydrogen (production) UNECE should address certain baseline considerations - concerns and expectations of the stakeholder community.

26. To begin with, adopting measurable reference points for renewable and low-carbon hydrogen does not necessarily correlate with conventional hydrogen "colored" classification.

[23] UNECE. (2020). Hydrogen – an innovative solution to carbon neutrality. Retrieved from https://unece.org/sites/default/files/2021-03/ECE_ENERGY_2020_8_Hydorgen_final.pdf.

[24] UNECE. (2020). Hydrogen – an innovative solution to carbon neutrality.

The first one assesses the sustainability of a product based on its carbon footprint during production. The second methodology relies on the essence of the production method itself. Accounting for innovation potential, one can expect that new approaches to hydrogen manufacturing will be developed in the future. Moreover, since "colors" of hydrogen are assigned quite arbitrarily (based on certain practices, perceptions, and associations), this approach leads to limited comparability of different manufacturing practices.

IV. The way forward - recommendations to ECE member States

27. Below are a number of recommendations, or options, available to ECE member States concerning the establishment of a GOH in the ECE region.

1. Principles for the GOH scheme as a part of a GO scheme for all energy carriers:

Principle 1. A GO system should be implemented for all energy carriers. When comparing different energy vectors, it is necessary to assess their environmental impact along the entire value chain. A comparable lifecycle analysis (LCA) "from cradle to grave" should be the foundation of a Guarantee of Origin (GO) system.

Principle 2. A *GOH should be a part of a comprehensive portfolio of interchangeable Guarantees of Origin (GOs) developed for all energy carriers*.

Principle 3. Cooperation and regulatory compatibility. Some countries/regions already have GOH certification in place. Finding a compromise is a prerequisite to globalization of the GOH scheme. International collaboration between existing certification structures could also facilitate knowledge exchange and harmonization of hydrogen regulations.

Principle 4. Flexibility: support, not impede. GOH is not a control mechanism - its main idea is to facilitate and create market dynamics. Thereby everything done in this respect should be in support of the GOH key beneficiaries (GO issuers and GO buyers)**.**

Principle 5. Simplicity and cost-efficiency. Repeating existing structures may be inefficient. Instead, the framework should be adjusted when some elements look expensive or unnecessary. For example, how could there be assurance that producers adhere to all manufacturing requirements after being GO-certified? Does it mean that each hydrogen batch produced with CCUS should be audited?

Principle 6. Technological neutrality and science-based approach. If metrics exist and quantitative comparison is possible – this should be prioritized over the qualitative approach. This recommendation concerns both standards for hydrogen production classification (emissions intensity) and the methodology and criteria for the certification procedure. Evaluator's accreditation, accreditors appointment, and any other elements of the scheme that require assessment and decision-making should be addressed respectively.

Principle 7. Maintaining the highest reputation. Transparency; impartiality; scientific soundness, relevance, and reality check; professionalism, and competency are behind the credible conformity scheme. If the GOH objective includes being "sought-after" and recognized as a global international instrument with an ultimately binding nature, the scheme management needs to win over the stakeholder community and gain its trust, and respect.

2. Develop clear rules of procedure for ECE-GOH. The rules should define functions, the internal structure of the scheme, key processes, responsible parties, and governing bodies. In terms of the GOH functions, at the very least it is recommended to outline the following:

- Enabling transparency, comparability, and benchmarking in the hydrogen sector with systematic hydrogen carbon intensity assessments
- Promoting renewable, low-carbon, and decarbonized hydrogen production through GOH labeling
- Encouraging trade and investments in sustainable hydrogen by introducing transferable decoupled GOH certificates.

3. Adopt objective and scientifically-derived classification for hydrogen production methods. The classification could be based on carbon intensity criteria. Until ECE members

develop their own indicators, the reference criteria could rely on the thresholds and benchmarks set out by the draft Delegated Act to the EU Taxonomy for Sustainable activities (Annex I25, paragraphs on hydrogen). That is, the following levels of intensity with the respected thresholds could be introduced: clean hydrogen (99.5 % of energy savings, where 0.5% corresponds to the maximum allowed CO2 leakage level; the category should apply both to renewable and decarbonized categories, distinguished by the manufacturing method itself); low-carbon hydrogen (73.4% for hydrogen/resulting in 3tCO2eq per tonne of hydrogen and 70% for hydrogen-based synthetic fuels), and carbon-intensive hydrogen (energy savings below the low-carbon threshold). The reference benchmark, as per the Taxonomy, could be a fossil fuel comparator of 94g CO2e/MJ.

4. **Provide freedom of discretion to ECE members to define other categories to be included in the GOH assessment.** According to the country's current priorities, the scheme could also provide qualifications for renewable hydrogen, hydrogen-CCUS production, nuclear hydrogen, and others. Where necessary, countries should envisage concluding mutual recognition agreements.

5. **Agree on an LCA-based methodology to qualify hydrogen production activities.** It is recommended that during the pilot phase the GOH assessment covers only the upstream level, namely: direct emissions from the immediate hydrogen manufacturing and CO_2 exhaust from the energy used to power hydrogen production (corresponds to Scope 1 and Scope 2 of the GHG protocol's taxonomy). In the future, the scope could be extended – where feasible – to cover other indirect emissions (Scope 3), midstream and downstream activities in the hydrogen value chain.

6. **Develop a comprehensive "unit conversion" table for hydrogen and a "carbon-intensity versus cost" comparative table for hydrogen production approaches.** Aside from general utility, these instruments could ameliorate implementation of the GOH scheme.

7. **Define common priorities, negotiate differences and agree on the collaborative activities** within the ECE region and among the extended UN family (through partnering with the UN regional commissions, UN agencies, and country-based UN offices). During the deliberations, the specific focus should be given to the GO "champions" like the European Union and Japan that have an established GO regulation. The interests and track record of key players in today's Hydrogen market – within and beyond the ECE borders – should also be given enhanced attention.

8. **Develop a necessary procedure for decommissioning of GOH** through, for example, a registry of issued GOH. Such a registry, based potentially on advanced technologies such as blockchain, is the only way to exclude double counting. Once a hydrogen molecule is destroyed/consumed, its guarantee of origin would expire as a balance sheet item but would be retained for reporting on GHG performance over the period in question.

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[25] EC. (2021). Annex to the Commission Delegated Regulation (EU) .../... supplementing Regulation (EU) 2020/852 of the European Parliament and of the Council by establishing the technical screening criteria for determining the conditions under which an economic activity qualifies as contributing substantially to climate change mitigation or climate change adaptation and for determining whether that economic activity causes no significant harm to any of the other environmental objectives. Retrieved from https://ec.europa.eu/finance/docs/level-2-measures/taxonomy-regulation-delegated-act-2021-2800-annex-1_en.pdf.