Beyond the Rainbow: Aligning Hydrogen Color Codes with CO_2 Emissions for a Transparent Energy Transition

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Abstract

Hydrogen is promoted as an essential building block in the energy transition, yet color codes used to describe its production pathways lack consistency. Color labels (e.g., green, blue, grey, black) are adopted in policy and industry discourse but fail to reflect carbon dioxide emissions. This article examines color classifications, building on an existing framework by expanding it through a qualitative assessment of recent literature. It analyzes how various production technologies - including water electrolysis powered by renewables, steam methane reforming, coal gasification, and nuclear-based processes - are labeled. Findings reveal significant inconsistencies, particularly for fossil-based and nuclear hydrogen, and highlight that renewable-based hydrogen is uniformly classified as green regardless of production specifics. The analysis suggests that if color codes were reassigned based on actual emissions, fossil-derived hydrogen would fall into a narrower, darker spectrum. These results call into question the compatibility of non-green hydrogen with climate objectives of the Paris Agreement.

Key words: green hydrogen, color code, carbon dioxide emissions, Paris Agreement
J.E.L. classification: M10

1. Introduction

This article revisits how hydrogen production methods are classified by color and proposes a restructured system that reflects carbon dioxide (CO_2) emissions rather than solely the technology or fuel used. The present work substantially builds upon the conference paper originally presented at the 17th International Conference on Business Excellence (Ocenic *et al*, 2023, p.111).

The primary aim is to develop a new color code for hydrogen that is grounded in scientific data regarding emissions associated with each production pathway—such as electrolysis using renewable or nuclear energy, steam methane reforming, or coal gasification, etc. This shift from technology-based to emission-based classification seeks to clarify industry practices, align with decarbonization goals, and enhance transparency for researchers, industry stakeholders, and policymakers. In doing so, the paper contributes to the broader dialogue on transitioning toward a sustainable hydrogen economy. Given the growing emphasis on "green" hydrogen in international climate policy contexts like the Paris Agreement, it becomes increasingly urgent to standardize terminology and promote a shared understanding of hydrogen production routes (Raman *et al*, 2022, p.9242).

The benefits of a unified color code extend beyond academic clarity. Color labels simplify communication around complex technological pathways, provide intuitive insights into carbon intensity—such as "green" indicating minimal emissions and "black" indicating high emissions—and assist in visually mapping relationships across different methods. This article adopts a qualitative comparative approach to assess whether there is currently a shared and consistent hydrogen classification framework in place. It tests two competing hypotheses: that such a harmonized color code does or does not exist in present literature and practice. Drawing on the foundational study by Nikolaidis and Poullikkas (Nikolaidis *et al*, 2017, p.609), this paper builds a critical assessment of hydrogen color coding through a literature-based comparison and graphical representation of classification inconsistencies.

Understanding and standardizing hydrogen classification holds relevance for business administration as well. A common taxonomy improves coordination within the hydrogen value chain, encourages consistency in marketing and regulatory compliance, and aids managers and investors in selecting sustainable production methods. Ultimately, this article illustrates that the current symbolic system of color codes is often misaligned, unregulated, and at times contradictory – calling into question whether hydrogen labels like "blue" or "grey" accurately reflect carbon performance. By identifying these gaps, this research lays the groundwork for a more rigorous and harmonized emissions-based framework that supports the development of sustainable and transparent hydrogen markets.

2. Theoretical background

2.1 Literature review

Hydrogen production has gained a global character, especially evident in the number and geographic distribution of planned projects (Ocenic, 2023a, p.477; Ocenic, 2024, p.1201). The classification of hydrogen by color has become convenient when discussing the carbon intensity of various production pathways. However, a growing body of literature reveals inconsistencies in terminology, lack of standardization, and regional discrepancies in the use of labels such as "green," "blue," "grey," and beyond (Ocenic, 2023b, p.460). This chapter surveys recent academic and institutional contributions to hydrogen color coding, with an emphasis on how these systems influence technological adoption, market structures, and investment decisions. Special attention is given to how the color code debate intersects with carbon accounting practices, certification mechanisms, and regulatory uncertainty in both EU and global contexts.

- Hydrogen production pathways

At present, 98% of global hydrogen is produced using fossil fuels (IRENA, 2022, p.7). Nonetheless, hydrogen generated through water electrolysis coupled with renewable energy sources – like hydropower, wind, or solar – is increasingly recognized as a crucial vector for enabling the low-carbon transition. This "green" hydrogen is particularly relevant for decarbonizing sectors that are traditionally difficult to electrify, including the iron and steel industry and aviation (IRENA, 2020a, p.4; Howarth *et al*, 2021, p.1677).

The academic literature provides various assessments of hydrogen production routes, among which the work of Nikolaidis and Poullikkas stands out for its comparative scope (Nikolaidis *et al*, 2017, p.597). Their study presents a structured overview of production methods that use both fossil-based feedstocks (oil, coal, natural gas) and renewable energy inputs (wind, solar, bioenergy), complemented by a visual mapping of the technological options.

However, despite its value, this overview shows notable omissions in light of current advancements. First, it does not include nuclear energy pathways, even though these fall within the author's stated scope. Second, the representation lacks emerging technologies such as hydrogen produced via microwave plasma reforming, a method recently gaining traction in academic discussions (Pocha *et al*, 2023, p.1). Third, although the term "green hydrogen" is used, the article does not clearly define the criteria for this classification, creating ambiguity in interpretation.

- Hydrogen colors: a spectrum without consensus

Although hydrogen is an invisible and colorless gas, the industry and academia have adopted a diverse color-coded system to denote its production methods—an irony often remarked upon by sector professionals (Giard, 2022). These labels span a wide spectrum, including white, green, grey, blue, black, brown, turquoise, yellow, orange, pink, red, and purple.

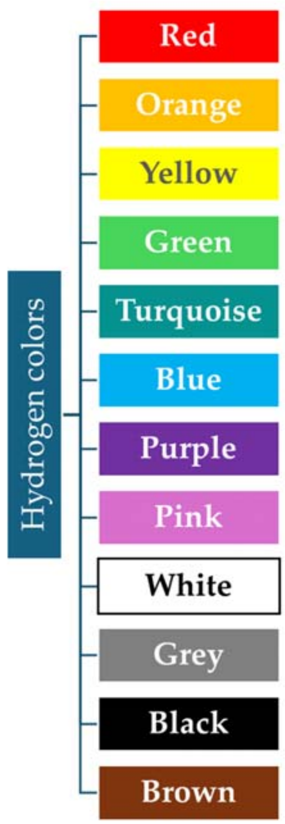
Despite the widespread use of these labels, there remains no consensus on what each color represents. The lack of standardization is evident across industry stakeholders, government policy, and academic publications. For example, institutions like the International Energy Agency (IEA) and the Hydrogen Council tend to avoid color-based classifications altogether (IEA, 2021, p.6), whereas the International Renewable Energy Agency recognizes specific colors such as green, grey, blue (IRENA, 2021, p.7), and sometime turquoise (IRENA, 2020b, p.8).

In the academic domain, Ringsgwandl et al. (Ringsgwandl *et al*, 2022, p.1) define “green” hydrogen as that produced via electrolysis using electricity exclusively sourced from renewables. Their framework also assigns other colors to additional pathways: “pink” for hydrogen produced using nuclear power and “yellow” for hydrogen generated from a mixed electricity grid (including both renewable and fossil sources).

However, this scheme presents several limitations. Firstly, it excludes several commonly cited colors, such as “brown” (Howarth *et al*, 2021, p.1677) and “black” (Osselin *et al*, 2022), which typically refer to hydrogen derived from coal or oil, thus offering only a partial taxonomy. Secondly, there are inconsistencies in how colors are used across sources. For instance, some scholars use “pink” to denote nuclear-sourced hydrogen and “yellow” for electrolysis with electricity from the grid which can be any source (Ringsgwandl *et al*, 2022, p.3), other studies define “pink” similarly (Ajanovic *et al*, 2022, p.24143) but describe “yellow” hydrogen as derived specifically from solar power (Acciona, 2022).

Figure no. 1 contains the colors identified by the author being currently used in the literature in connection to hydrogen produced via different technologies from different sources.

Figure no. 1. Hydrogen color codes used by researchers, businesses and institutions



Source: Author’s own research results

2.2 Socio-technical transitions theory

Multi-level perspective (MLP) theory frames socio-technical transitions as evolving processes shaped by multiple interacting levels along three analytical layers: the landscape (macro), regime (meso), and niche (micro), whereby niche refers to innovations or “radical novelties” (Geels, 2004, p.910). In the context of hydrogen classification, the "landscape" includes macro-drivers such as the Paris Agreement (United Nations, 2015) at international level, the European Green Deal (European Commission, 2019) within the European Union, and – more generally – global decarbonization targets. These forces pressure existing "regimes," which include regulatory frameworks, incumbent energy and industry actors, and industrial norms that rely on legacy classification schemes.

At the "niche" level, emerging frameworks like a proposed carbon-dioxide-based hydrogen color code challenge the regime by offering a more transparent, simple, yet evidence-based approach aligned with emissions accounting and climate goals. The introduction of such classification systems can disrupt current market logic and enable new forms of energy governance, supporting the diffusion of low-carbon technologies and consumer trust.

By reframing hydrogen technologies and related colors as a socio-technical innovation, we expose how symbolic tools (like color codes) shape market incentives, business behavior, influence technological choices, and impact policy design. The transition toward a carbon-dioxide-based color code thus represents more than a semantic shift—it reflects a broader systemic reconfiguration.

Generative artificial intelligence was used to rephrase some ideas that were initially published in the conference paper that was presented at the 17th International Conference on Business Excellence (Ocenic *et al*, 2023).

3. Research methodology

To investigate the inconsistency of hydrogen color labels and propose a harmonized alternative, this paper adopts a qualitative, interpretive methodology grounded in comparative document analysis. Drawing from academic literature, institutional reports, and policy documents, it maps the range of hydrogen production technologies and associated color labels. This is followed by a simplified classification framework. It also incorporates visual analysis tools to illustrate inconsistencies in current classifications, and it proposes a new, carbon dioxide emissions (CO_2) based typology for future use.

This paper extends the foundational work of Nikolaidis and Poullikkas (Nikolaidis *et al*, 2017) by expanding the comparative review with the most recent academic and institutional literature and examining whether a shared understanding exists regarding which production methods correspond to which color labels in the hydrogen lexicon.

3.1 Dominant research question

The dominant research question guiding the present analysis is:

Is there a widely accepted and harmonized color code that accurately and consistently maps hydrogen production technologies to specific colors?

Two hypotheses are tested:

H_1: A standardized, commonly accepted color code exists across literature, institutions and industry.

H_2: No such harmonized system exists, and color usage varies significantly across sources.

3.2 Methodological approach

To address this question, the research follows a four-stage methodological approach:

- Literature review

A comprehensive review of peer-reviewed publications, technical reports, and position papers from international organizations involved in hydrogen strategy and policymaking is conducted. The goal is to map existing knowledge on hydrogen production methods and their corresponding color labels.

- Comparative analysis

The second phase involves a systematic comparison of the visual and textual depictions of hydrogen production pathways found in the literature. This includes classifying technologies based on both the feedstock (e.g., natural gas, coal) and conversion process (e.g., electrolysis, gasification, reforming). Where color codes are present, these are documented and compared across sources.

- Graphical redesign and enrichment

Building on the initial framework proposed by Nikolaidis and Poullikkas (Nikolaidis *et al*, 2017), the paper constructs a new and enriched graphical representation of hydrogen production methods.

This updated diagram incorporates additional technologies sourced from recent literature (Akubo *et al*, 2019; Osselin *et al*, 2022; Pocha *et al.*, 2023; Okeke *et al*, no date).

- Colour mapping and visual coding

In the final step, each hydrogen production pathway is assigned one or more colors based on the findings from the literature review. In cases where a technology is labelled with multiple colors in different sources, the visual illustration reflects these variations using a gradient color indicator to represent the inconsistencies.

Following this process, this article offers a more holistic and structured view of hydrogen production technologies and their symbolic color representations. If all sources converge on the same color for a given technological pathway, the first hypothesis is supported. If multiple colors are assigned to a single technology – or if the same color refers to different methods – the findings validate the second hypothesis, suggesting a lack of consistency in the current system.

Ultimately, this research seeks to evaluate whether the color code system reflects a coherent, widely accepted classification scheme, and to propose a refined version based on carbon dioxide emissions from each production pathway.

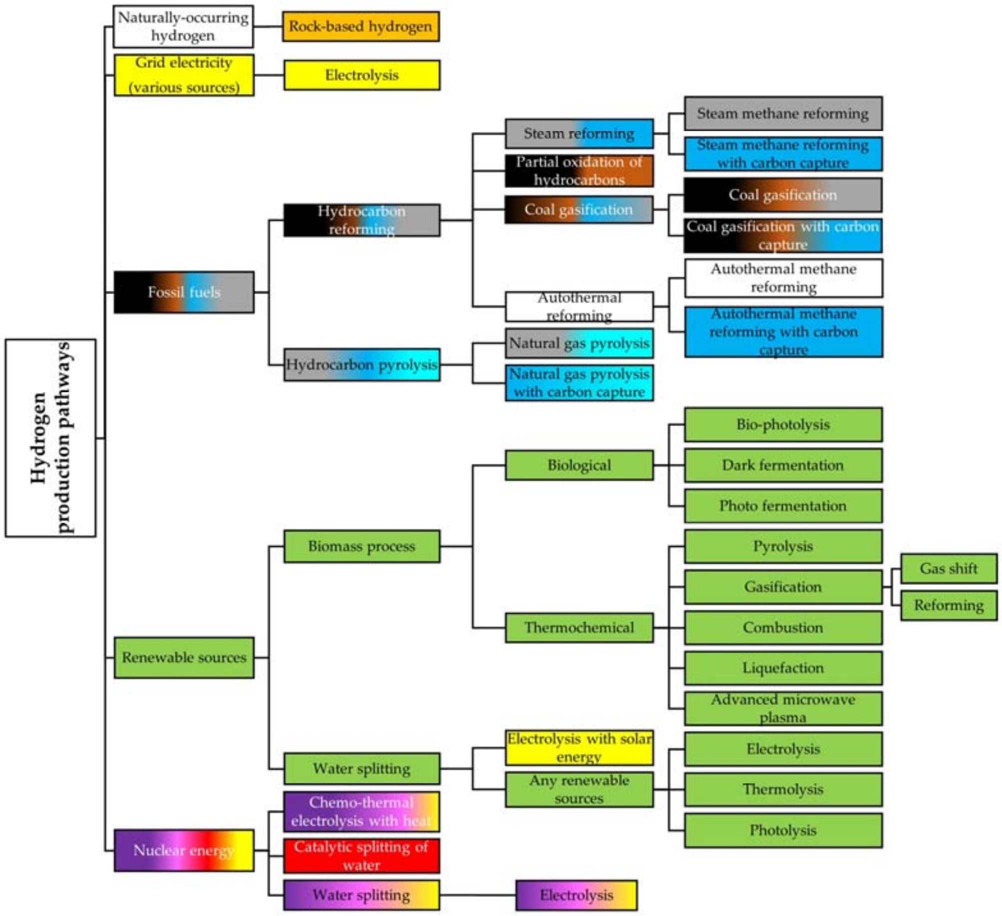
4. Findings

4.1 Comparative analysis of hydrogen color schemes

This section presents a comparative overview of hydrogen color classification schemes (Ocenic *et al*, 2023, p.117) used by governments, international organizations, industry actors, and researchers, as presented in Figure no. 2. The analysis reveals major discrepancies in how similar production technologies are labeled across jurisdictions. Focus is put on the inconsistencies in color coding for fossil-based hydrogen, hydrogen produced using nuclear energy, and electrolysis with electricity from the grid which can come from various energy sources. Through this comparison, this article highlights the risks posed by inconsistent labeling, including consumer confusion, regulatory loopholes, and distorted investment signals.

Each production pathway in this visual is assigned one or more colors based on how it is labeled across various sources. In cases where a specific technology is associated with multiple colors in the literature, these discrepancies are depicted using gradients that reflect the full range of identified color codes—whether two, three, or more variations.

Figure no. 2. Colors representing different hydrogen production pathways



Source: (Ocenic *et al*, 2023, p.117)

4.2 Inconsistencies in color labelling hydrogen production pathways

As evidenced in Figure no. 2, the application of this methodology highlights substantial inconsistencies in how hydrogen colors are attributed to different production technologies, particularly those involving fossil fuels. Nuclear-powered hydrogen production also displays notable variation in color labeling across sources.

At first glance, it may appear that a logical and structured color system is in place: for example, "green" hydrogen refers to production via renewable electricity, "black" is linked to fossil fuel-based pathways, and "pink" typically denotes nuclear-powered electrolysis. While such labeling conventions may appear internally consistent within individual papers or frameworks, this comparative analysis reveals a lack of alignment across the broader literature. This results in overlapping and, at times, contradictory classifications.

A closer examination reveals that even where partial consensus exists—such as in the case of "pink" hydrogen referring to electrolysis powered by nuclear energy—additional labels like "red," "purple," or "yellow" are also used for the same technology in other sources. These contradictions are problematic. For instance, Ringsgwandl et al. associate "yellow" hydrogen with electrolysis powered by a grid electricity mix, encompassing both fossil and renewable inputs (Ringsgwandl *et al*, 2022, p.3). However, some industrial actors (Acciona, 2022) define "yellow" hydrogen as a solar-powered subcategory of "green" hydrogen.

Further complicating matters, the definition of "green" hydrogen has evolved over time. Originally used exclusively for hydrogen produced via electrolysis with renewable electricity, the term is now often applied to any hydrogen generated from renewable sources – including biomass-based methods. The only recurring deviation from this broader definition is the labeling of solar-powered hydrogen as "yellow" by specific industry actors, as mentioned previously.

From a policy perspective, there is likewise no universal taxonomy. For example, the European Commission's Hydrogen Strategy for a Climate-Neutral Europe avoids using color classifications altogether. Instead, it defines "renewable hydrogen" as hydrogen "produced through the electrolysis of water (in an electrolyser, powered by electricity), and with the electricity stemming from renewable sources" (European Commission, 2020, p.3), with negligible greenhouse gas emissions. The strategy also extends the definition to include hydrogen obtained by "reforming of biogas (instead of natural gas) or biochemical conversion of biomass" (European Commission, 2020, p.4), provided these methods meet established sustainability criteria.

Even greater ambiguity arises in the classification of hydrogen derived from fossil fuels. Terms such as "black," "grey," and "brown" are often used interchangeably depending on the source, without clear criteria. For example, hydrogen produced via pyrolysis of hydrocarbons is sometimes categorized as "grey," similar to conventional gas-based hydrogen, while other sources refer to it as "turquoise," often without a clearly articulated rationale.

One notable point of convergence across sources is the use of the term "blue" hydrogen to describe fossil-based hydrogen production coupled with carbon capture and storage (CCS) technologies. That appears to be the only category where some degree of consensus has emerged.

In the case of naturally occurring hydrogen, often referred to as geologic or subterranean hydrogen, researchers have informally labeled it as "white" hydrogen—even though hydrogen itself is inherently colorless. This categorization underscores the symbolic nature of the color system. Interestingly, the passive extraction of naturally present hydrogen has been proposed as a substitute for established production methods, which use active chemical or electrochemical processes. One such approach involves injecting water into subsurface ferrous rock formations to release hydrogen – a method known as "orange" hydrogen, named for its association with the oxidation process that produces rust-colored iron deposits (Osselin *et al*, 2022, p.765).

A significant limitation of the current hydrogen color taxonomy is that it does not comprehensively cover all existing or emerging production technologies. As new methods are developed, the absence of a theoretical, empirical, or even intuitive framework for assigning colors raises concerns about the sustainability of the color-based classification system itself. There is a real risk of "running out" of distinct and meaningful colors to represent future innovations.

For instance, hydrogen produced via autothermal methane reforming currently lacks a widely accepted color label. Although it might be considered within the broader category of fossil fuel-derived hydrogen – and thus theoretically fall under labels such as grey, brown, or black – there is no clear consensus in the literature.

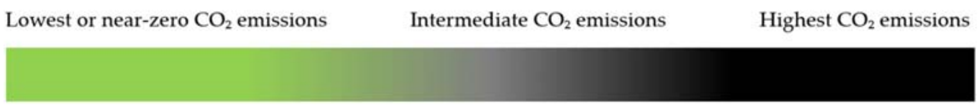
Furthermore, when attempting to visually represent carbon dioxide emissions using a color-coded system – anchored in the widely held assumption that "green" signifies negligible emissions while "black" indicates high emissions—hydrogen derived from fossil fuels tends to cluster toward the higher-emission end of the spectrum. This reduces the practical differentiation among fossil-based methods despite their varied technical characteristics. As illustrated in Figure no. 2, this convergence suggests that the current color palette overstates the diversity of fossil-based hydrogen pathways while underrepresenting the need for an emissions-based reclassification framework.

Instead of relying on the current classification of fossil-based hydrogen as "blue," a more accurate representation—based on actual carbon dioxide emissions—would categorize hydrogen produced from coal, oil, or natural gas into varying shades of "black." A CO_2-based emissions scale would reveal that the climate impact of these production methods is often greater than what existing color codes imply.

Given that the global hydrogen debate is driven largely by the urgent need to decarbonize multiple sectors of the economy in line with international climate targets, this insight has critical implications for scientific, policy, and industrial discourses. This paper questions whether any hydrogen variant other than "green" – defined here as hydrogen obtained with renewable energy sources like wind, solar, hydropower, or bioenergy – can truly align with the emissions reduction objectives outlined in the Paris Agreement (United Nations, 2015, p.4).

Considering the inconsistencies and lack of systematic rationale in the current hydrogen color scheme, this paper advocates abandoning the existing color taxonomy altogether. The current palette includes an incoherent mix of primary (red, yellow, blue), secondary (green, orange, purple), and tertiary colors (turquoise, brown), alongside tints like pink or achromatic colors like grey, black, and white – all of which are applied arbitrarily, without reference to any recognized color theory (Munsell, 1905).

Figure no. 3. New three-color-coded labeling proposed (green, gray, black) for hydrogen production technologies, reflecting carbon dioxide emissions



Source: Adapted from (Ocenic *et al*, 2023, p.118)

As an alternative, this article proposes adopting a simplified and standardized three-color system: green, grey, and black, as shown in Figure no. 3. This scheme would be directly tied to the carbon dioxide emissions intensity of hydrogen production methods, expressed in terms of tons of carbon dioxide emitted per kilogram of hydrogen obtained. The classification is technology-neutral and does not require special treatment for processes that incorporate carbon capture technologies—their benefits would naturally be reflected through lower emissions values.

Drawing on the Munsell color model (Munsell, 1905), the three-color scale would range from black (highest emissions), through grey (intermediate emissions), to green (lowest or near-zero emissions). This visual framework would allow for more intuitive and scientifically grounded comparisons between hydrogen production technologies, thereby enhancing public understanding and supporting the strategic planning necessary for the global transition from a global economy powered by fossil fuels to a carbon-neutral one. It would also create a more logical point of comparison for hydrogen produced using nuclear energy, which currently occupies an ambiguous place in the color taxonomy.

In this model, green hydrogen would be reserved for technologies using renewable energy with minimal emissions; black hydrogen would apply to high-emission fossil-fuel-based methods; and grey hydrogen would cover transitional pathways—such as fossil-based hydrogen with carbon capture and storage. The precise emissions thresholds that define these categories remain a subject for future empirical research.

The adoption of a harmonized, CO_2-based color code has far-reaching implications for both policymakers and market actors. For regulators, such a system could strengthen alignment with carbon pricing mechanisms, investment taxonomy regulations, and hydrogen certification initiatives like the EU Hydrogen Bank (European Commission, no date). For businesses, it offers a tool to reduce reputational and compliance risks while enabling more informed investment decisions.

5. Conclusions

This research paper presents three key findings.

First, contrary to initial appearances, there is no unified, harmonized, or widely accepted color code for categorizing the diverse technological pathways used to produce hydrogen, therefore the first hypothesis is rejected and the second one is accepted. While there is general agreement that "green" hydrogen means hydrogen obtained thanks to renewable energy sources via various methods, the classification of hydrogen derived from fossil fuels and nuclear energy remains inconsistent and often contradictory. The multitude of color labels applied by both academia and industry contributes to considerable confusion in understanding hydrogen production technologies.

Second, the paper discusses an enhanced and more inclusive graphical representation of hydrogen production pathways, developed through a comparative analysis of the most recent scientific literature. This new visual framework not only captures a broader range of production technologies but also maps out the inconsistent application of color labels found across academic sources and industry communications. As such, it offers a more comprehensive review of the current landscape of technologies for the production of hydrogen and its labels.

Third, it challenges the validity and usefulness of the existing complex color codes, arguing that they are overly complicated, inconsistent, and lacking any systematic scientific rationale. In response, the paper proposes a simplified three-color system – green, grey, and black – grounded in the amount of carbon dioxide emitted during hydrogen production. This classification draws inspiration from Munsell's color theory and prioritizes transparency, coherence, and practical relevance over symbolic ambiguity.

The contribution of this article lies in its critique of the prevailing classification systems and its proposal for a streamlined alternative that better reflects the environmental footprint of technological pathways to produce hydrogen. By introducing a CO_2-based model, this research supports the harmonization of terminology and decision-making across policy, industry, and academia.

From a theoretical perspective, the study advances the understanding of hydrogen production classifications by synthesizing and analyzing diverse literature sources and presenting an updated visual framework. This serves as a valuable resource for researchers, policymakers, and stakeholders seeking clarity in an increasingly complex and fragmented field.

From a managerial standpoint, the proposed three-color code offers a user-friendly tool to inform investment decisions and guide strategic planning. By directly linking hydrogen classification to carbon intensity, this model enables business leaders, investors, and public officials to assess technologies based on environmental performance and align actions with decarbonization objectives.

Nonetheless, this study has certain limitations. Notably, it does not provide specific CO_2 emission thresholds for each color category within the proposed framework. Additionally, the findings are based solely on a literature review and have not yet been validated through empirical research. Future work could involve expert consultation, such as a targeted questionnaire, to test the robustness of the proposed framework and gather practical feedback on its utility in real-world decision-making.

6. References

- Acciona, 2022. *What Are The Colours Of Hydrogen And What Do They Mean?* [online] Acciona. Available at: https://www.acciona.com.au/updates/stories/what-are-the-colours-of-hydrogen-and-what-do-they-mean [Accessed 17 June 2025].
- Ajanovic, A., Sayer, M. and Haas, R., 2022. The economics and the environmental benignity of different colors of hydrogen. *International Journal of Hydrogen Energy*, 47(57), pp.24136–24154. https://doi.org/10.1016/j.ijhydene.2022.02.094.
- Akubo, K., Nahil, M.A. and Williams, P.T., 2019. Pyrolysis-catalytic steam reforming of agricultural biomass wastes and biomass components for production of hydrogen/syngas. *Journal of the Energy Institute*, 92(6), pp.1987–1996. https://doi.org/10.1016/j.joei.2018.10.013.
- European Commission, 2019. *Communication on The European Green Deal.* [online] Available at: https://commission.europa.eu/document/daef3e5c-a456-4fbb-a067-8f1cbe8d9c78_en [Accessed 16 June 2025].
- European Commission, 2020. *A hydrogen strategy for a climate-neutral Europe*. [online] Available at: https://energy.ec.europa.eu/system/files/2020-07/hydrogen_strategy_0.pdf [Accessed 18 June 2025.
- European Commission, no date. *European Hydrogen Bank - European Commission*. [online] Available at: https://energy.ec.europa.eu/topics/eus-energy-system/hydrogen/european-hydrogen-bank_en [Accessed 18 June 2025].
- Geels, F.W., 2004. From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy*, 33(6), pp.897–920. https://doi.org/10.1016/j.respol.2004.01.015.
- Giard, M., 2022. Post | LinkedIn. [online] Available at: https://www.linkedin.com/posts/matthieu-giard_hydrogen-planet-activity-6914558927158345729-mA0J/ [Accessed 16 June 2025].
- Howarth, R.W. and Jacobson, M.Z., 2021. How green is blue hydrogen? *Energy Science & Engineering*, 9(10), pp.1676–1687. https://doi.org/10.1002/ese3.956.
- IEA, 2021. *Global Hydrogen Review 2021 – Analysis*. [online] IEA. Available at: https://www.iea.org/reports/global-hydrogen-review-2021 [Accessed 16 June 2025].

- IRENA, 2020a. *Reaching Zero with Renewables*. Abu Dhabi: International Renewable Energy Agency. Available at: https://www.irena.org/publications/2020/Sep/Reaching-Zero-with-Renewables [Accessed 9 June 2023].
- IRENA, 2020b. *Green hydrogen: A guide to policy making*. Abu Dhabi: International Renewable Energy Agency. Available at: https://www.irena.org/Publications/2020/Nov/Green-hydrogen [Accessed 10 June 2023].
- IRENA, 2021. *Making the breakthrough: Green hydrogen policies and technology costs*. Abu Dhabi: International Renewable Energy Agency. Available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Nov/IRENA_Green_Hydrogen_breakthrough_2021.pdf?la=en&hash=40FA5B8AD7AB1666EECBDE30EF458C45EE5A0AA6.
- IRENA, 2022. *Decarbonising End-use Sectors: Green Hydrogen Certification.* Abu Dhabi: International Renewable Energy Agency. Available at: https://www.irena.org/publications/2022/Mar/The-Green-Hydrogen-Certification-Brief [Accessed 16 June 2025].
- Munsell, A.H., 1905. *A Color Notation.* G. H. Ellis Co. [online] Available at: http://archive.org/details/acolornotation00munsgoog [Accessed 26 January 2023].
- Nikolaidis, P. and Poullikkas, A., 2017. A comparative overview of hydrogen production processes. *Renewable and Sustainable Energy Reviews*, 67, pp.597–611. https://doi.org/10.1016/j.rser.2016.09.044.
- Ocenic, E., 2023a. Trends in Hydrogen Production Projects for Energy and Climate Purposes – A Descriptive Analysis of the IEA Database. In: *Knowlegde Based Sustainable Development: Vol 9. Conference Proceedings. ERAZ Conference*, Association of Economists and Managers of the Balkans. https://doi.org/10.31410/ERAZ.2023.475.
- Ocenic, E., 2023b. Harmonizing Hydrogen Colour Codes: Need for an Economic Policy Framework for a Global Hydrogen Market. *Ovidius University Annals*. Economic Sciences Series, 23, pp.458–465. https://doi.org/10.61801/OUAESS.2023.1.60.
- Ocenic, E., 2024. "Green" Hydrogen Products and Their Economic End-Uses: A Statistical Perspective. *Proceedings of the International Conference on Business Excellence*, 18(1), pp.1197–1211. https://doi.org/10.2478/picbe-2024-0102.
- Ocenic, E. and Tanțău, A., 2023. Redefining the Hydrogen "Colours" based on Carbon Dioxide Emissions: A New Evidence-Based Colour Code. *Proceedings of the International Conference on Business Excellence,* 17, pp.111–121. https://doi.org/10.2478/picbe-2023-0013.
- Okeke, I.J., Saville, B.A. and MacLean, H.L., no date. Low carbon hydrogen production in Canada via natural gas pyrolysis - ScienceDirect. *International Journal of Hydrogen Energy*. [online] Available at: https://www.sciencedirect.com/science/article/abs/pii/S0360319922058852?via%3Dihub [Accessed 16 June 2025].
- Osselin, F., Grosjean, N., Truche, L., Bureau, H., Curtil, C. and Gautier, J., 2022. Orange hydrogen is the new green. *Nature Geoscience*, 15(10), pp.765–769. https://doi.org/10.1038/s41561-022-01043-9.
- Pocha, C.K.R., Hariram, V., Godson, L. and Vignesh, V., 2023. Thermochemical conversion of different biomass feedstocks into hydrogen for power plant electricity generation. *Fuel*, 340, p.127472. https://doi.org/10.1016/j.fuel.2023.127472.
- Raman, R., Rajendran, M., Krishnamurthy, R. and Esakkimuthu, S., 2022. Green-hydrogen research: What have we achieved, and where are we going? Bibliometrics analysis. *Energy Reports*, 8, pp.9242–9260. https://doi.org/10.1016/j.egyr.2022.07.058.
- Ringsgwandl, L.M., Schwenk, C., Albrecht, F.G., Krumm, A. and Schill, W.P., 2022. Current Legislative Framework for Green Hydrogen Production by Electrolysis Plants in Germany. *Energies*, 15(5), p.1786. https://doi.org/10.3390/en15051786.
- United Nations, 2015. *The Paris Agreement*. [online] Available at: https://unfccc.int/process-and-meetings/the-paris-agreement [Accessed 9 June 2023].