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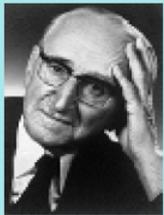
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Ordnungspolitische Diskurse

Discourses in Social Market Economy



**J. Meitz, D. Faude, L. Strauch, V.I. Kämpf,
M. Gläß & U. Walther**

**Hydrogen Engines as a Building Block of
European Energy Autonomy: Acceptance
Factors and Political Decisions**

Diskurs 2026 - 2

Hydrogen Engines as a Building Block of European Energy Autonomy: Acceptance Factors and Political Decisions

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Abstract:

The European Union has set forth an objective to reduce its reliance on fossil fuels and external supply chains. Hydrogen technologies are regarded as a pivotal element in achieving a sustainable and resilient energy supply. Despite the prioritization of hydrogen-powered fuel cells in numerous strategies, hydrogen combustion engines also offer promising opportunities, particularly with regard to heavy-duty applications and industrial processes. The successful deployment of this technology hinges upon its societal acceptance. The present paper analyzes, on the basis of empirical studies, the determinants influencing the acceptance of hydrogen engines in various societal and economic contexts. In doing so, it takes into account the political, infrastructural, and technological framework conditions. Additionally, the paper explores the potential contributions of the promotion of hydrogen engines to the European Union's strategic autonomy in the energy sector. Finally, policy recommendations have been formulated to support broader societal acceptance and the economic implementation of this technology.

Key Words:

Societal Acceptance, Energy Autonomy, European Union Policy, Decarbonization, Hydrogen Internal Combustion Engines

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1. Hydrogen as a Cornerstone of European Energy Policy

The European Union, through its Hydrogen Strategy, aims to establish hydrogen as a central pillar of a climate-neutral energy future by 2050. The strategy constitutes an integral component of the *European Green Deal* and positions hydrogen as a key element for the decarbonization of industrial processes, transport, and energy supply (European Commission, 2020a). A central geopolitical motive is the reduction of dependence on fossil energy imports, particularly from Russia (European Commission, 2023). In response to the war against Ukraine and the resulting energy crisis, the expansion of renewable energies – including green hydrogen – has been massively accelerated (Marhold, 2023, p. 764). At the same time, the EU faces the challenge of reducing its dependency on energy imports: in 2022, the import share amounted to 62.5 %, with a particularly high vulnerability in oil and gas (Dulian, 2024). In light of this, the EU aims to build an integrated European hydrogen market. The focus lies on strengthening security of supply and consolidating Europe's global leadership in future technologies (European Commission, 2020b).

The 2050 outlook envisions that hydrogen will account for approximately 10 % of Europe's total energy demand. This target is embedded in a hydrogen economy that is defined as climate-neutral, competitive, and resilient. According to the available evidence, close networking between industry, politics, and civil society is foreseen, alongside the establishment of joint standards, certification schemes, and infrastructure projects (European Commission, n.d.).

Given an unstable geopolitical environment characterized by trade conflicts, competition for raw materials, and questions of technological sovereignty, the EU has intensified its call for strategic autonomy – understood as the capacity to secure key energy and technology sectors through its own resources (Yildiz Bravo, 2023, p. 403; Deirmentzoglou et al., 2024, p. 1). However, the political framework continues to be marked by competence conflicts between the EU level and the Member States. Considering multiple crises – from the war in Ukraine to climate change and fluctuations in prices and supply – numerous stakeholders are calling for a recalibration of energy policy decision-making structures (Marhold, 2023, p. 757). A strategically aligned, coordinated, and anticipatory energy policy is considered key to managing the transformation

2. Production, Utilization, and Integration of Hydrogen in Key Sectors

2.1 Hydrogen Production: Technologies, Potentials, and Challenges

The question of hydrogen production is central to the future role of hydrogen technologies in the European energy mix. While EU strategies have so far focused primarily on fuel cells and end-use applications, it is ultimately the method of production that determines ecological sustainability, economic viability, and societal acceptance.

At present, hydrogen is predominantly produced from fossil sources such as natural gas and coal, resulting in significant CO₂ emissions (Ji & Wang, 2021, p. 38612). Increasingly, however, low-emission processes such as electrolysis powered by renewable electricity are coming to the fore, gaining competitiveness through declining costs and technological advancements (Osman et al., 2021, p. 153; Ji & Wang, 2021, p. 38612). Nevertheless, no single production pathway meets all ecological and economic requirements, making hybrid and site-specific solutions appear most viable for the future (Hamid et al., 2025, p. 1).

In the long term, technological progress, technology-neutral support schemes, and strategic site selection will be decisive in building a robust hydrogen economy that contributes to the EU's energy autonomy and enjoys societal acceptance.

2.2 Hydrogen in Mobility and Industry: Pathways and Strategic Relevance

Hydrogen is gaining increasing importance in the commercial vehicle sector and in industry – both for achieving climate neutrality and for enhancing the resilience of the European energy system.

In the heavy-duty transport sector, it offers advantages such as long range, short refueling times, and flexible refueling infrastructure (Fraunhofer, n.d.). In addition to fuel cell vehicles, which are already being deployed in the logistics sector, manufacturers are also advancing hydrogen combustion engines: MAN plans to deploy test fleets starting in 2025, while other producers and suppliers are working on dual-fuel systems and jet-ignition spark-ignition engines (BMW Group, 2021; Amann & Carey, 2024; Boretta, 2020, p. 23692). These technologies make use of existing infrastructure, reduce dependency on scarce raw materials, and thereby enhance security of supply and

system resilience (Onorati et al., 2022, p. 530). Research and practical testing have gained considerable momentum in recent years (Turner et al., 2024, p. 606; Shinde & Karunamurthy, 2022, p. 1568).

In industry, hydrogen is regarded as a key enabler for decarbonizing energy-intensive processes. In particular, hydrogen-based direct reduction enables significant emission reductions in steel production. Carbon capture and utilization (CCU) processes also open new perspectives for a circular raw materials economy (Fraunhofer, n.d.). Furthermore, H₂-fired power plants and fuel cells contribute to grid stability and security of supply, while hydrogen can substitute fossil fuels in high-temperature processes in the chemical, glass, or cement industries (Fraunhofer, n.d.). As such, it represents not only a building block for CO₂ reduction but also a means of strengthening Europe's technological sovereignty.

3. Societal Acceptance as a Key Enabler for Strategic Hydrogen Transformation

Societal acceptance constitutes a central prerequisite for the successful diffusion of hydrogen-based technologies. Irrespective of technological feasibility and political support, the extent to which hydrogen technologies are integrated into everyday life and work contexts largely determines whether they can be widely implemented in the domains of mobility, households, and industry. European studies generally document a positive basic attitude toward hydrogen and fuel cell technologies but simultaneously point to limited awareness and a persistent need for information; country-specific differences are mostly rated as low to moderate (Oltra et al., 2017, p. 2; Emodi et al., 2021, p. 30581). Within this constellation, level of knowledge, perceived benefits and risks, and clearly identifiable enabling conditions function as key determinants that can be deliberately addressed by policymakers and practitioners.

The Technology Acceptance Model (TAM) provides a well-established theoretical framework for explaining the acceptance and use of technological innovations (Davis, 1989; Venkatesh & Davis, 2000; Venkatesh et al., 2003; Venkatesh & Bala, 2008). According to the TAM approach, the willingness to adopt a technology essentially rests on two core expectation dimensions: the perceived usefulness in everyday life (e.g., contribution to climate protection, extended range, improved security of supply) and

the anticipated ease of use (e.g., aspects of refueling, maintenance effort, operational convenience). In the context of hydrogen applications, these fundamental dimensions are modified by specific contextual factors, including the availability and visibility of infrastructure, individual technical knowledge and perceived information transparency, trust in established safety standards, and subjective cost perceptions. Infrastructural conditions represent a fundamental prerequisite for everyday integration; knowledge reduces uncertainty; increased trust in safety standards mitigates perceived risk; and cost perception negatively influences the overall assessment of usefulness. The current literature on hydrogen mobility confirms these mechanisms and further highlights the reciprocal feedback between a positive perception of hydrogen-powered vehicles and societal support for accompanying infrastructure expansion measures (Huan et al., 2024, p. 1; Le et al., 2024, p. 791). In the domestic, everyday context, domain-specific models such as the Domestic Hydrogen Acceptance Model (DHAM) additionally consider the importance of emotional evaluations alongside cognitive assessment in shaping acceptance of hydrogen technologies (Gordon et al., 2022, p. 1; Gordon et al., 2024, p. 498).

Against this backdrop, an online survey conducted by the authors (N = 187) provides concrete points of reference. The analysis of participants' mobility behavior reveals a marked preference for individual transport: 63 % of respondents predominantly use a car, while 23 % regularly rely on public transportation. Self-assessments of information levels are distributed primarily across the categories "partial" (39 %) and "good" (33 %), while 15 % of respondents rated their knowledge as "low" and 12 % as "very good," indicating identifiable and potentially addressable knowledge gaps. The main barriers to the implementation of renewable energies primarily include insufficiently developed infrastructure and high investment costs, supplemented by technical limitations and a lack of information or public awareness. With regard to hydrogen, deficiencies in infrastructure (60 mentions) and insufficient information (56 mentions) are identified as the most significant challenges; cost-related aspects (27 mentions) and safety concerns (17 mentions) are cited less frequently but still represent relevant barriers. Approximately 75 % of respondents stated that sound information and education on the safe handling of hydrogen would positively influence their attitude toward the technology.

The survey identifies key influencing factors in the areas of risk communication, education, and technological visibility. These findings align consistently with the acceptance framework. First, a visible and reliable infrastructure increases the anticipated functionality and perceived everyday usability of hydrogen applications, while the required effort for use is considered low. Targeted information and training measures, particularly regarding safety procedures, standards, and emergency protocols, foster trust among stakeholders and reduce the perceived relevance of hypothetical risk factors. Moreover, subjective perceptions of cost structures significantly shape the overall evaluation of benefits, particularly during the initial phases of market adoption. Social influence factors – for instance, those experienced in application-oriented exhibition environments – can significantly increase acceptance, willingness to adopt, and support for infrastructural innovations. Together, these mechanisms form a coherent system: more precise anticipation of everyday user requirements and greater transparency regarding safety aspects promote a more favorable attitude toward the technology, while increased infrastructure presence correlates with a higher perception of hydrogen technologies as a realistic course of action.

Empirical analyses of European research confirm that attitudes are predominantly determined by perceived benefits, emotional factors, and sociodemographic characteristics (Oltra et al., 2017, p. 2). Infrastructure, affordability, local integration, safety, and fair distribution of benefits are identified as key determinants, with overall awareness levels remaining low in most of the analyzed countries (Emodi et al., 2021, p. 30669). Recent reviews and meta-analyses (Le et al., 2024, p. 791; Huan et al., 2024, p. 1) demonstrate that educational measures, public outreach, and the visibility of practical use cases significantly enhance acceptance and that positive attitudes toward vehicles translate into a higher willingness to support corresponding infrastructure developments. Conceptual frameworks in the context of hydrogen adoption emphasize the necessity of an integrative analysis of interactions between individual attitudes, political-institutional structures, market mechanisms, and observed behavior (Gordon et al., 2022, p. 1), while the Dynamic Heuristic Adoption Model (DHAM) highlights the relevance of affective factors in everyday decision-making situations (Gordon et al., 2024, p. 498).

Societal acceptance thus represents a key resource for the successful implementation of the strategic hydrogen transformation, as it aggregates collective expectations regarding benefits, practicality, safety, and fairness, thereby decisively shaping the feasibility of political steering approaches. The combination of a generally positive attitude, identified knowledge gaps, and a pronounced willingness to embrace change within the surveyed sample indicates considerable potential for development. Societal acceptance therefore constitutes a fundamental prerequisite for building a strategically autonomous hydrogen economy within the European context.

4. Environmental Considerations, Infrastructure, and Regulation as Building Blocks of Strategic Energy Autonomy

The environmental impacts of hydrogen are largely determined by the production pathway. Production via electrolysis powered by renewable energy sources is particularly advantageous, as it enables the highest potential emission reductions. Other production methods, despite technological progress, remain associated with disadvantages, while production without CO₂ capture is increasingly regarded as unsustainable (Osman et al., 2021, p. 153; Riemer et al., 2022, p. 2). Climate-friendly hydrogen shows particular potential in hard-to-decarbonize sectors such as heavy-duty transport and industrial process heat (Seck et al., 2022, p. 1).

For large-scale deployment, a robust infrastructure and a clear regulatory framework are essential. High production costs, substantial electricity and water demand, as well as insufficient transport and storage networks are currently considered the main obstacles (Sebbagh et al., 2024, p. 4017). The EU therefore prioritizes the expansion of production, transport, and storage capacities – for instance, by deploying electrolyzers at locations with abundant renewable energy, establishing a pan-European pipeline network, and creating large-scale seasonal storage facilities such as salt caverns (Fleiter et al., 2024, p. 1). A comprehensive refueling station infrastructure is also crucial for the market introduction of fuel cell vehicles, yet its expansion remains slow and hesitant (Genovese & Fragiaco, 2023, p. 1).

Success depends on cooperation between industry, research, and policymakers, supported by targeted funding instruments and financing models (Hamid et al., 2025, p.

1). At the same time, risks such as material shortages, import dependencies, and geopolitical tensions pose challenges to the stable development of the sector (Battaglini & Ceglarz, 2023, p. 2). Nevertheless, hydrogen remains central to grid flexibility and energy storage and is thus considered a cornerstone of a resilient energy system (Fuel Cells and Hydrogen 2 Joint Undertaking, 2019, p. 39).

At the political level, the EU is promoting initiatives such as the European Clean Hydrogen Alliance to coordinate the entire value chain. The objective is to remove investment barriers, foster international cooperation, and ensure market ramp-up by 2030 (European Commission, n.d.). Germany plays a leading role in this context, yet there are still coordination deficits in infrastructure and supply chains (Singh et al., 2025, p. 1). Moreover, political uncertainty – such as unclear responsibilities or fluctuating funding programs – hampers investment and prolongs permitting procedures (Algburi et al., 2025, p. 1). A binding, long-term, and consistent regulatory framework is therefore indispensable to build trust and establish hydrogen as a cornerstone of an energy-autonomous European Union.

5. Europe's Strategic Sovereignty in the Context of Hydrogen Policy

Hydrogen is regarded as a key lever for strengthening European energy autonomy. It reduces emissions, increases the flexibility of energy systems, and can decrease import dependencies (DLR, 2020). Since countries such as Germany cannot fully exploit their renewable energy potential, targeted imports from regions rich in solar and wind resources will be required. This necessitates early investments in terminals, pipeline networks, storage facilities, and conversion plants, as well as a coordinated market and regulatory design that ensures planning security (Hydrogen Europe, 2024, p. 26).

In parallel, the EU is embedding its Energy Union as a strategic instrument to guarantee security of supply, deepen the internal energy market, and promote innovations such as hydrogen (European Commission, 2025). Complementary policy instruments—such as recycling quotas for critical metals or eco-design regulations for electrolyzers—are gaining importance in order to strengthen resource security and the circular economy (Axt et al., 2025, p. 1). In the long term, hydrogen is expected to trans-

form the geography of energy trade: regional partnerships based on renewable resources create new opportunities but also entail new dependencies (IRENA, 2022, p. 29; Marhold, 2023, p. 1).

The planned scale-up also entails significant risks. Through the REPowerEU strategy, the European Commission aims to produce and import ten million tonnes of hydrogen each by 2030. This ambitious target significantly exceeds current capacities and poses major implementation challenges (Battaglini & Ceglaz, 2023, p. 5). One key risk lies in inefficient allocation: if hydrogen is used in sectors that could be electrified, it may be lacking where it is most difficult to substitute, such as in high-temperature industrial processes or heavy-duty transport.

There is also the risk of increasing import dependency. Since a substantial share of demand is expected to be covered by third countries, vulnerability to geopolitical conflicts, competitive pressure, and unstable supply regions will rise (Battaglini & Ceglaz, 2023, p. 7). Societal acceptance is likewise not guaranteed: the high costs of infrastructure and system integration could trigger resistance if benefits and burdens are perceived as unevenly distributed.

What is needed, therefore, is a differentiated and prioritized hydrogen strategy that simultaneously accounts for efficiency, sectoral suitability, and geopolitical resilience. Only then can hydrogen become a cornerstone—rather than a potential weak point—of European energy policy.

6. Conclusions and Strategic Implications

The present analysis highlights the significant potential of hydrogen technologies – particularly hydrogen combustion engines – as a fundamental component of the European Union’s strategic energy autonomy. Beyond technical and political feasibility, societal acceptance is decisive for the successful implementation of the hydrogen transition. It aggregates expectations regarding benefits, practicality, and safety, and substantially influences the enforceability of policy initiatives. It is therefore essential that available data be analyzed with due diligence.

The online survey (N = 187) indicates that, despite a generally positive attitude toward hydrogen and fuel cell technologies, there remains a significant need for information and education. Respondents identified insufficient infrastructure and lack of public awareness as the main barriers. Conversely, sound education on safe handling of hydrogen could strengthen trust and positively affect acceptance. To sustainably enhance acceptance and ensure transformation, a systematically coordinated approach is indispensable. The EU should therefore:

- Accelerate the development of a visible and reliable hydrogen infrastructure, as this increases the perceived suitability for everyday use.
- Intensify societal participation and public awareness campaigns to deliberately close information gaps.
- Promote targeted research and development on combustion-based hydrogen applications to enable short-term utilization of existing industrial infrastructure. Create political and economic incentives that facilitate widespread industrial adoption while taking efficiency and sectoral suitability into account.

The establishment of hydrogen as a cornerstone of a climate-neutral and geopolitically sovereign energy future for Europe can only be achieved through a systematically coordinated, technology-open, and resilience-oriented approach. In this context, public acceptance must be recognized as a central criterion for success.

References

- Algburi, S., Al-Dulaimi, O., Fakhrudeen, H., Khalaf, D., Hanoon, R., Jabbar, F., Hassan, Q., Al-Jiboory, A., Kiconco, S. (2025)** The green hydrogen role in the global energy transformations. *Renewable and Sustainable Energy Transition*, 8, 100118.
- Amann, C., & Carey, N. (2024)** Big truckmakers bet on hydrogen to extend combustion engine life, online: <https://www.reuters.com/business/autos-transportation/big-truckmakers-bet-hydrogen-extend-combustion-engine-life-2024-08-01/> (accessed 13 August 2025).
- Axt, M., Baldassarre, B., & Kirchherr, J. (2025)** Towards greater circularity in the hydrogen technology value chain. *Ecological Economics*, 236, 108679.
- Battaglini, A., & Ceglaz, A. (2023)** The role of hydrogen in a future, low carbon, and secure European energy system, online: https://renewables-grid.eu/fileadmin/user_upload/Files_RGI/RGI_Publications/Hydrogen_Paper/The_role_of_hydrogen_in_a_future_low_carbon_and_secure_European_energy_system_website.pdf (accessed 21 August 2025).
- BMW Group (2021)** Innovationstreiber der Wasserstoff-Technologie für eine nachhaltige, CO₂-freie Mobilität von morgen, online: <https://www.press.bmwgroup.com/deutschland/article/detail/T0329390DE/innovationstreiber-der-wasserstoff-technologie-fuer-eine-nachhaltige-co2-freie-mobilitaet-von-morgen> (accessed 13 August 2025).
- Boretti, A. (2020)** Hydrogen internal combustion engines to 2030. *International Journal of Hydrogen Energy*, 45(43), 23692-23703.
- Davis, F. (1989)** Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, 13(3), 319-340.
- Deirmentzoglou, G., Anastasopoulou, E., & Sklias, P. (2024)** International economic relations and energy security in the European Union: a systematic literature review. *International Journal of Sustainable Energy*, 43(1), 2385682.
- DLR (2020)** Grüne Wasserstoffwirtschaft: Sektorenkopplung und internationale Zusammenarbeit als Erfolgsfaktoren, online: https://www.dlr.de/de/aktuelles/nachrichten/2020/03/20200930_dlr-studie-wasserstoff-als-fundament-der-energiewende (accessed 21 August 2025).
- Dulian, M. (2024)** Security of energy supply, online: [https://www.europarl.europa.eu/RegData/etudes/BRIE/2024/762410/EPRS_BRI\(2024\)762410_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/BRIE/2024/762410/EPRS_BRI(2024)762410_EN.pdf) (accessed 13 August 2025).
- Emodi, N., Lovell, H., Levitt, C., & Franklin, E. (2021)** A systematic literature review of societal acceptance and stakeholders' perception of hydrogen technologies. *International Journal of Hydrogen Energy*, 46(60), 30669-30697.
- European Commission (2020a)** COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS - A hydrogen strategy for a climate-neutral Europe, online: <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0301> (accessed 13 August 2025).

European Commission (2020b) Wasserstoffstrategie für ein klimaneutrales Europa, online:

https://ec.europa.eu/commission/presscorner/api/files/attachment/865951/EU_Hydrogen_Strategy_DE.pdf.pdf (accessed 13 August 2025).

European Commission (2023) ANNEX to the Commission Decision on the signing on behalf of the European Commission of the Joint Declaration on Hydrogen Valleys - Moving the hydrogen economy from niche to scale, online: https://research-and-innovation.ec.europa.eu/document/download/bc8f9bde-9fe3-4604-9097-bde5d03c9f02_en?filename=C_2023_1131_F1_ANNEX_EN_V4_P1_2523210.PDF (accessed 13 August 2025).

European Commission (2025) In focus: Completing Europe's energy union, online: https://energy.ec.europa.eu/news/focus-completing-europes-energy-union-2025-06-16_en (accessed 21 August 2025).

European Commission (n.d.) Hydrogen, online: https://energy.ec.europa.eu/topics/eus-energy-system/hydrogen_en?prefLang=de (accessed 13 August 2025).

Fleiter, T., Fragoso, J., Lux, B., Alibaş, Ş., Al-Dabbas, K., Manz, P., Neuner, F., Weißenburger, B., Rehfeldt, M., Sensfuß, F. (2024) Hydrogen Infrastructure in the Future CO₂-Neutral European Energy System—How Does the Demand for Hydrogen Affect the Need for Infrastructure? *Energy Technology*, 13(2), 2300981.

Fraunhofer (n.d.) Nutzung von Wasserstofftechnologien in der Industrie, Strom- bzw. Wärmeerzeugung und Mobilität, online: <https://www.fraunhofer.de/de/forschung/fraunhofer-strategische-forschungsfelder/wasserstofftechnologien/nutzung-von-wasserstofftechnologien-in-der-industrie--strom--bzw.html> (accessed 13 August 2025).

Fuel Cells and Hydrogen 2 Joint Undertaking (2019) Hydrogen Roadmap Europe: A sustainable pathway for the European Energy Transition, online: https://www.clean-hydrogen.europa.eu/document/download/b4ea2b61-a7da-4484-a522-1b2232bff134_en?filename=Hydrogen%20Roadmap%20Europe_Report.pdf (accessed 21 August 2025).

Genovese, M., & Fragiaco, P. (2023) Hydrogen refueling station: Overview of the technological status and research enhancement. *Journal of Energy Storage*, 61, 106758.

Gordon, J., Balta-Ozkan, N., & Nabavi, S. (2022) Beyond the triangle of renewable energy acceptance: The five dimensions of domestic hydrogen acceptance. *Applied Energy*, 324, 119715.

Gordon, J., Balta-Ozkan, N., & Nabavi, S. (2024) Towards a unified theory of domestic hydrogen acceptance: An integrative, comparative review. *International Journal of Hydrogen Energy*, 56, 498-524.

Hamid, A., Deris, R., Shaffee, S., Hin, T., Ametefe, D., & Ibrahim, M. (2025) A systematic review on environmentally friendly hydrogen production methods: comparative analysis of reactor technologies for optimal efficiency and sustainability. *Sustainable Chemistry for Climate Action*, 6, 100088.

Huan, N., Yamamoto, T., Sato, H., Sala, R., & Goncalves, L. (2024) Perceptions to connections: A multidimensional investigation of hydrogen acceptance. *Renewable and Sustainable Energy Reviews*, 200, 114612.

Hydrogen Europe (2024) Hydrogen Infrastructure Report The Recipe for a Hydrogen Grid Action Plan, online: https://hydrogeneurope.eu/wp-content/uploads/2024/10/2024.09_HE_Hydrogen-Infrastructure-Report-1.pdf (accessed 21 August 2025).

IRENA (2022) Geopolitics of the Energy Transformation: The Hydrogen Factor, International Renewable Energy Agency. Abu Dhabi.

Ji, M., & Wang, J. (2021) Review and comparison of various hydrogen production methods based on costs and life cycle impact assessment indicators. *International Journal of Hydrogen Energy*, 46(78), 38612-38635.

Le, T., Sharma, P., Bora, B., Tran, V., Truong, T., Le, H., & Nguyen, P. (2024) Fueling the future: A comprehensive review of hydrogen energy systems and their challenges. *International Journal of Hydrogen Energy*, 54, 791-816.

Marhold, A.-A. (2023) Towards a 'security-centred' energy transition: balancing the European Union's ambitions and geopolitical realities. *Journal of International Economic Law*, 26, 756-769.

Oltra, C., Dütschke, E., Sala, R., Schneider, U., & Upham, P. (2017) The public acceptance of hydrogen fuel cell applications in Europe. *Revista internacional de Sociología*, 75(2).

Onorati, A., Payri, R., Vaglieco, B., Agarwal, A., Bae, C., Bruneaux, G., Canakci, M., Gavaises, M., Günthner, M., Hasse, C., Kokjohn, S., Kong, S.-C., Moriyoshi, Y., Novella, R., Pesyridis, A., Reitz, R., Ryan, T., Wagner, R., Zhao, H. (2022) The role of hydrogen for future internal combustion engines. *International Journal of Engine Research*, 23(4), 529-540.

Osman, A., Mehta, N., Elgarahy, A., Hefny, M., Al-Hinai, A., Al-Muhtaseb, A., & Rooney, D. (2021) Hydrogen production, storage, utilisation and environmental impacts: a review. *Environmental Chemistry Letters*, 20, 153-188.

Riemer, M., Wachsmuth, J., Pfluger, B., & Oberle, S. (2022) Welche Treibhausgasemissionen verursacht die Wasserstoffproduktion?, online: https://www.umweltbundesamt.de/sites/default/files/medien/479/dokumente/uba_welche_treibhausgasemissionen_verursacht_die_wasserstoffproduktion.pdf (accessed 20 August 2025).

Sebbagh, T., Şahin, M., & Beldjaatit, C. (2024) Green hydrogen revolution for a sustainable energy future. *Clean Technologies and Environmental Policy*, 26, 4017-4040.

Seck, G., Hache, E., Sabathier, J., Guedes, F., Reigstad, G., Straus, J., Wolfgang, O., Ouassou, J., Askeland, M., Hjorth, I., Skjelbred, H., Andersson, L., Douguet, S., Villavicencio, M., Trüby, J., Brauer, J., Cabot, C. (2022) Hydrogen and the decarbonization of the energy system in Europe in 2050: A detailed model-based analysis. *Renewable and Sustainable Energy Reviews*, 167, 112779.

Shinde, B., & Karunamurthy, K. (2022) Recent progress in hydrogen fuelled internal combustion engine (H2ICE) – A comprehensive outlook. *Materials Today: Proceedings*, 51(3), 1568-1579.

Singh, V., Aishwarya, V., Sriprasath, V., Pranavi, M., Kavya, R., & Singh, T. (2025) Green hydrogen value chain challenges and global readiness for a sustainable energy future. *iScience*, 28(7), 112900.

Turner, J., Verhelst, S., & Marquez, M. (2024) The potential of hydrogen internal combustion engines for heavy-duty applications. In R. Shabaneh, J. Roychoudhury, J. Braun, & S. Saxena (Eds.), *The Clean Hydrogen Economy and Saudi Arabia* (pp. 606-637). London: Routledge.

Venkatesh, V., & Bala, H. (2008) Technology acceptance model 3 and a research agenda on interventions. *Decision Sciences*, 39(2), 273–315.

Venkatesh, V., & Davis, F. (2000) A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science*, 46(2), 186-204.

Venkatesh, V., Morris, M., Davis, G., & Davis, F. (2003) User acceptance of information technology: Toward a unified view. *MIS Quarterly*, 27(3), 425–478.

Yildiz Bravo, S. (2023) Strategic autonomy of the European Union: reality or utopia? A critical analysis of its main dimensions and obstacles. *Journal of the Spanish Institute for Strategic Studies*, 22, 399-421.

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