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REGULATORY GAPS IN HYDROGEN TECHNOLOGY IN THE SHADOW OF THE GREEN TRANSITION: COMPLEX LEGAL AND SAFETY-TECHNICAL ANOMALIES IN THE ESTABLISHMENT OF HYDROGEN REFUELLING STATIONS

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ABSTRACT

The development of hydrogen-based transport and energy storage depends on a coherent regulatory framework adapted to the technology's specific characteristics. Based on an analysis of the Hungarian regulatory environment, this study argues that hydrogen-related rules remain fragmented, creating administrative burdens and investment uncertainty for market participants. The paper examines taxation, urban planning, occupational safety, and fire protection rules, with particular attention to deficiencies in excise regulation and the safety-technical gaps of the National Hydrogen Strategy.

The analysis shows that the lack of defined excise tax rates, the quality assurance shortcomings of NFM Decree 17/2017, and the strict installation restrictions of the National Telecommunications and Infrastructure Framework hinder both investment and the development of residential hydrogen infrastructure. In the absence of detailed domestic rules, market actors and authorities are often forced to rely on international standards, which only partly compensate for regulatory gaps.

The study concludes that technological development has outpaced legislation and that targeted legal intervention is needed. It proposes the adoption of an independent hydrogen-specific disaster management guide, the harmonisation of intervention protocols with domestic legal frameworks, and the supplementation of the Technical Guidelines for Fire Protection with explosion-protection requirements. The findings underline that the objectives of the National Hydrogen Strategy cannot be achieved without integrating safety-technical considerations and resolving permitting anomalies affecting green technologies.

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The article offers a regulatory roadmap for legislators and technical planners seeking to reduce risks arising from the current regulatory hiatus.

KEYWORDS Hydrogen economy, regulatory gaps, excise taxation, explosion safety, disaster management protocols

1. The Fundamentals of the Regulatory Environment for Hydrogen

In Hungary, the integration of hydrogen technology is currently being implemented within the framework of existing occupational safety, fire protection, technical-safety, and environmental norms; however, this fragmented framework obstructs technological progress and dampens investment appetite at several points. In the absence of a standalone structure tailored to the specificities of the technology, legal practitioners are frequently forced to rely on analogies or international recommendations in daily practice, which increases legal uncertainty and the potential for error. Although Act CXVII of 2010 is of fundamental importance with regard to the use of renewable energy for transport purposes, it only promotes the expansion of hydrogen as an alternative fuel in a general framework, without providing concrete implementation instructions for investors. While NFM Decree 17/2017 (V. 26.) on the quality requirements of motor fuels already includes parameters for electricity and CNG/LNG beyond traditional fuels, it does not yet provide for the quality requirements of hydrogen; therefore, supplementing the legislation in this area is an unavoidable task.

To bridge this gap, the application of the MSZ EN ISO 14687 standard has become widespread in international practice, as it sets out in detail the purity categories of hydrogen fuel – parameters that are critical for the lifespan of fuel cells. Due to this regulatory hiatus, investors themselves must define quality expectations vis-à-vis suppliers, which increases legal risks. The issue of fuel quality is not merely a technical matter but also raises consumer protection concerns, as hydrogen of inadequate purity can cause irreversible damage to the fuel-cell systems of vehicles. The legislator should strive to ensure that specific purity and sampling protocols for hydrogen are recorded in domestic decrees, in alignment with European Union directives. The current state, in which designers must establish quality guarantees on the basis of foreign standards, causes unnecessary administrative complications during licensing procedures. Due to the lack of legal regulation, spheres of liability also become blurred, which may lead to lengthy legal disputes between the operator and the fuel supplier in the event of a technical failure.

From an economic perspective, the most significant obstacle is represented by the deficiencies in excise regulation, which act as a direct barrier to market-based proliferation and long-term business planning. In its current form, Act LXVIII of 2016 does not define a specific tax rate for hydrogen as a motor fuel, which is an untenable situation for sectoral players, as economic returns become unpredictable. This regulatory deficiency creates significant economic uncertainty for operators, as illustrated by the case of the first Hungarian hydrogen refuelling station (HRS), where the lack of clarity regarding excise regulation and tax warehouse frameworks contributed significantly to the temporary shutdown. The legal determination of hydrogen's excise status and precise tax rate is essential for the sector's development, as its absence deters potential domestic and foreign investors. The legislator must recognize that the clarification of the economic environment for hydrogen can wait no longer, as the current vacuum hinders the realization of goals set out in the National Hydrogen Strategy and the fulfilment of climate protection commitments (ITM; 2021).

Uncertainties surrounding tax warehouse licensing indicate that authorities are also unprepared to handle hydrogen as a fuel, further increasing the administrative burdens on investors. The lack of coherence in the regulatory environment is not merely a theoretical problem but a factor that renders daily operations impossible, requiring urgent legislative intervention at all levels. Due to tax uncertainty, the banking sector also deems hydrogen projects risky, making it difficult to secure external funding for infrastructure development. During the clarification of excise regulation, the environmental benefits of green hydrogen should be taken into account, potentially encouraging its spread over fossil energy carriers through tax incentives.

The current regulatory environment distorts market competition, as it places hydrogen at a disadvantage compared to other alternative fuels, such as electricity. Due to the lack of clear legal frameworks, domestic companies face a competitive disadvantage vis-à-vis market players in neighbouring countries, where regulation is already further advanced.

2. Urban Planning Constraints and Anomalies in Environmental Permitting

The establishment process for hydrogen refuelling stations (HRSs) is further complicated by recently introduced stringent urban planning regulations, which are often inconsistent with the technology's actual risk profile. Pursuant to Government Decree 280/2024 (IX. 30.) (TÉKA), it is prohibited to install HRSs in small-town, suburban, and village residential areas, as well as in holiday zones; this effectively excludes the technology from the vicinity of residential districts,

thereby hindering network development. Construction licensing procedures are regulated by Government Decree 281/2024 (IX. 30.) and Government Decree 31/2014 (II. 12.) on specific industrial structures; the latter deviates from general residential building rules due to technological complexity.

Under the current Hungarian settlement-planning framework, the issue is no longer governed by Government Decree 314/2012 (XI. 8.), but primarily by Government Decree 419/2021 (VII. 15.) and the TÉKA, introduced by Government Decree 280/2024 (IX. 30.). The TÉKA recognises protective areas, safety zones, protective strips and protection distances as instruments serving protection against harmful effects or ensuring safety. Their extent and the conditions for their use and development must be determined on the basis of sector-specific legislation or, in the absence of such legislation, by the competent authorities. Where no clear environmental threshold or hydrogen-specific domestic sizing rule exists, the minimum required protection distance may therefore be determined on a case-by-case basis. This does not prevent such zones from being recorded in settlement-planning instruments, but it may create uncertainty for designers and authorities and may lead to conservative land-use restrictions. In the case of hydrogen infrastructure, such uncertainty may hinder deployment in residential or mixed-use areas where demand for clean energy solutions is likely to be highest.

While the regulation for specific industrial structures allows for individual assessment, in practice authorities often remain cautious due to a lack of precedents. In urban planning, the designation of protection zones is crucial for the public perception of safety, but these should be based on precise scientific data. Current regulation fails to differentiate between smaller stations storing a few hundred kilograms of hydrogen and large industrial tank farms, thereby imposing a disproportionately heavy burden on smaller investors.

In the field of environmental permitting, serious contradictions emerge, creating significant administrative barriers to the on-site production of green hydrogen. Under Government Decree 314/2005 (XII. 25.), on-site hydrogen production at refuelling stations would fall within the scope of integrated environmental permitting, regardless of whether it involves environmentally friendly electrolysis. This obligation remains even if the hydrogen is produced using renewable energy – a clearly green technology – yet it is treated as a major industrial environmental pollutant during the procedure. In its current form, the government decree is unnecessary, unjustified, and represents a significant obstacle to the installation of HRSs with on-site production, as it forces investors into complex and lengthy environmental licensing procedures (Zero Carbon Hub, 2021).

The decree does not distinguish between fossil-based and green hydrogen production methods, which distorts market competition and slows the achievement of national decarbonisation goals. A legislative amendment would be justified in order to exempt small-scale, green-based on-site electrolysers from the strictest examinations, thereby facilitating infrastructure development. The novelty of the technology also presents difficulties for environmental authority experts, which in practice often leads to requests for supplementary information and further unjustified delays in the procedure. A fundamental prerequisite for sustainable transport is the simplification of on-site production, as this reduces transport costs and associated environmental impacts.

Legislators must recognize that environmental regulation should encourage, rather than hinder, the spread of eco-friendly alternatives. During domestic harmonisation with the EU IPPC and IED directives, the unique character of relatively small-scale production at refuelling stations should be taken into account. The current environmental permitting process is so time-consuming that many investors opt for hydrogen transport instead, which increases logistical risks and greenhouse gas emissions during road transport. Simplifying the licensing of on-site electrolysers would be key to establishing a decentralised hydrogen economy in Hungary.

3. Operational Safety and Technical Compliance for Hydrogen Systems

The obligations imposed on employers during the operation of hydrogen technology are established by the framework of Act XCIII of 1993 on Occupational Safety and Health, which is further detailed by MüM Decree 5/1993 (XII. 26.) on the implementation of certain provisions of the Occupational Safety Act. In the presence of hydrogen, the employer is required to implement technological measures that prioritize the prevention of explosive atmospheres, such as the application of forced ventilation. Pursuant to Joint Decree 3/2003 (III. 11.) FMM–ESZCSM on the minimum safety and health requirements for work in potentially explosive atmospheres, operators must develop site-specific explosion protection documentation (EPD/ATEX) for every hydrogen refuelling facility. Workers operating in potentially explosive workspaces must receive specialized training, be familiarized with the EPD, and participate in regular evacuation drills along designated escape routes. Regarding electrical equipment, NGM Decree 40/2017 (XII. 4.) on the safety requirements for electrical installations stipulates the installation and operational rules for devices belonging to hydrogen's II.C gas group. Concerning personal protective equipment, workplace use of PPE is regulated by EüM Decree 65/1999 (XII. 22.), while PPE product-compliance requirements are governed by Regulation (EU)

2016/425. Rather than prescribing a uniform set of equipment for all workers, this framework requires employers to determine and provide appropriate PPE on the basis of workplace risk assessment. For hydrogen-related operations involving flammable gas, explosive atmospheres or electrostatic ignition hazards, this may include antistatic footwear and flame-retardant or antistatic protective clothing.Furthermore, NGM Decree 10/2016 (IV. 5.) on the safety requirements for pressure equipment and systems requires regular, documented technical inspections of high-pressure compressors to maintain safe operations.

Compliance with occupational safety regulations is not merely a legal necessity but a fundamental safety pillar, considering hydrogen's odourlessness and invisible flame. Based on Joint Decree 3/2002 (II. 8.) SzCsM–EüM on the minimum level of safety and health requirements for workplaces, facilities must ensure adequate air exchange and the physical demarcation of safety zones from unauthorized personnel. During the construction phase, Joint Decree 4/2002 (II. 20.) SzCsM–EüM on the minimum safety and health requirements to be implemented at construction sites regulates the work organization principles to be applied during the laying of high-pressure pipelines.

As domestic decrees contain few hydrogen-specific provisions, the international system of standards provides the most critical guidance for designers and operators. The purity of hydrogen as a fuel is a critical factor, for which MSZ EN ISO 14687 and MSZ EN 17124:2022 serve as the basis, establishing quality assurance requirements. For the physical design of stations, MSZ EN 17127:2024 regarding outdoor refuelling station protocols and MSZ EN ISO 17268:2020 for connection technology are authoritative. The backbone of hydrogen technology safety is formed by the MSZ EN 13237:2013 and MSZ EN 1127-1:2019 standards, the latter being particularly important with regard to non-sparking tools used in Zone 0. The significance of MSZ EN ISO 7539-11:2015 must be highlighted, as it examines the resistance of metals to hydrogen embrittlement, which is essential for material selection in high-pressure tanks. Technical guidelines issued by the European Industrial Gases Association (EIGA), such as EIGA Doc 15/21 or EIGA Doc 134/21, fill the gaps in national regulations, providing engineering support for the precise designation of protection zones.

Additionally, ISO 19880-1:2020, an internationally recognized foundational document for hydrogen stations, sets strict safety requirements for the performance-based placement of gas detection systems. Although the application of standards is not always mandatory by law, in practice, they constitute the expected technical level (state of the art), and authorities conduct inspections on that basis. During engineering design, these documents consolidate decades of industry experience; thus, their application is

indispensable for risk minimization. Materials science challenges, particularly metal embrittlement caused by high-pressure hydrogen, require continuous research and regular updates of standards. In the field of machinery safety, MSZ EN ISO 12100:2011 on risk reduction and MSZ EN 60204-1:2019 on the safety of electrical equipment provide the basic frameworks for station manufacturers. Control system safety is guaranteed by the MSZ CLC IEC/TR 61511-0:2022 standard on functional safety, which aims to ensure the reliability of software-based protection systems.

4. Disaster Management Frameworks and Emergency Response Protocols

Pursuant to Act XXXI of 1996 on Fire Protection, Technical Rescue, and Fire Brigades, HRSs are classified as facilities of strategic economic and safety importance, requiring specialized regulatory oversight. Consequently, a Firefighting and Technical Rescue Plan (TMMT) must be developed in cooperation with the professional fire services, incorporating hydrogen-specific extinguishing procedures and safety rules for intervention. Under Government Decree 219/2011 (X. 20.) on the protection against major-accident hazards involving dangerous substances, exceeding hydrogen threshold quantities may classify the facility as a hazardous establishment (Seveso III), mandating the preparation of rigorous safety analyses. While the National Fire Safety Regulations (OTSZ), established by BM Decree 54/2014 (XII. 5.), discuss various flammable and explosive gases, they still lack specific provisions explicitly applicable to HRSs, causing significant difficulties in legal application (Nagy & Bencs, 2023). Although the Technical Guideline for Fire Protection (TvMI) 13.5:2025.02.01 classifies hydrogen as a high-intensity explosive category, it sets no clear requirements for refuelling stations, though it does record the sizing of explosion pressure relief surfaces.

Regarding transport safety and disaster risk prevention, the road transport of hydrogen as a dangerous good is regulated under the ADR framework. In Hungary, the currently applicable ADR Annexes A and B are promulgated by Government Decree 165/2025 (VI. 24.), while certain aspects of domestic application are governed by ITM Decree 39/2021 (VII. 30.). This framework sets out the applicable requirements for the classification, packaging, tank or cylinder transport, vehicle marking, documentation and ADR training of drivers involved in the carriage of dangerous goods. Fire-safety conformity assessment is addressed separately by Government Decree 492/2017 (XII. 29.), which regulates the designation of organizations authorized to examine, inspect and certify the fire-safety compliance of certain technical products. In addition, NGM Decree 35/2014 (XI. 19.) establishes technical safety requirements for the

operation of certain transportable pressure equipment and contains the Gas Cylinder Safety Code, including requirements relevant to the filling, inspection, marking and structural integrity of gas cylinders.

The unique physical properties of hydrogen – the invisibility of its flame and the odourlessness of the gas – require a novel approach and specialized equipment from responding personnel. In the event of an accident, reconnaissance must be performed by a minimum of two persons equipped with thermal imaging cameras and personal gas detectors, with vehicles positioned at least 50 metres away, outside the safety zone and with due regard to wind direction. Fires caused by gas discharge must not be extinguished until the hydrogen supply has been isolated by closing the system; instead, efforts should concentrate on the intensive cooling of tanks using remote-controlled monitors to prevent explosion. The dispersion of the gas cloud must be restricted using U-shaped water shields at a distance of 5–10 metres from the leak, ensuring that the wind drifts the cloud toward the water curtain for dilution (Bérczi et al., 2024).

If units cannot commence intensive cooling within 10 minutes, preparations must be made for tank rupture due to internal pressure increase, and a full area evacuation must be ordered. Spraying tanks containing refrigerated (cryogenic) hydrogen with water is strictly prohibited to avoid thermal shock, and combustible materials must be removed from the endangered environment. Following fire suppression, cooling must continue until the risk of reignition is completely eliminated, accompanied by continuous gas concentration monitoring until the full inspection of the area is complete. During intervention, only non-sparking equipment and explosion-proof devices are permitted, in close professional cooperation with the operator. During the preparation of responding personnel, emphasis must be placed on handling cryogenic liquids and high-pressure leaks, as provided by professional training under BM Decree 9/2015 (III. 25.) on the training of the professional disaster management staff. Firefighters must be familiar with the thermal radiation characteristics of hydrogen flames, as they can cause severe burns from great distances even without visible light.

5. Conformity Assessment, Certification, and Challenges in Commissioning

A hydrogen refuelling station (HRS) is classified as a hazardous installation; therefore, prior to being placed on the market, it must possess a fire safety conformity certificate pursuant to ÖM Decree 22/2009 (VII. 23.) on the rules for the certification of fire safety or technical rescue compliance of certain fire-fighting or technical rescue equipment and facilities. A designated certification body must be involved in the process based on Section 20 of Act XXXI of 1996

on Fire Protection, Technical Rescue, and Fire Brigades, as an accredited examination is mandatory before the introduction of any fire- or explosion-hazardous technology. It is important to highlight that documentation certifying the conformity of individual sub-assemblies is insufficient to verify the collective CE conformity of the assembled equipment, which imposes significant liability on the contractor. According to NGM Decree 40/2017 (XII. 4.) on the safety requirements for electrical installations, the contractor must hand over the as-built design documentation, the machine manual, and the inspection reports for the electrical equipment.

In the case of high-pressure vessels, an EU type-examination certificate in accordance with the PED (2014/68/EU) Directive is indispensable and must be issued by an independent Notified Body (NoBo). The operation of conformity assessment bodies is regulated by Act CXXXIII of 2009 on the activities of conformity assessment bodies, ensuring their independence and professional competence, while Government Decree 315/2009 (XII. 28.) on the detailed rules for the designation of conformity assessment bodies sets out the strict order for their appointment to guarantee the credibility of test results. Furthermore, hydrogen technology components, such as electrolyzers or compressors, must also comply with the requirements of the Machinery Directive (2006/42/EC). In many cases, certification includes restrictions regarding the inspection of tank safety mechanisms, which the type-examination certificate generally does not cover; therefore, the verification of safety systems must still be approved prior to commissioning (Bérczi et al., 2024). Such critical elements may include the placement of pressure relief valves or the securing of cylinder valves, to which the manufacturer draws specific attention in the manual.

For investors, certified conformity is not only a legal obligation but also a fundamental prerequisite for safe operation and liability insurance. The certification body must review the entire documentation for the HRS and perform the necessary inspections for each technological unit. Due to the complexity of the process, investors should involve experts as early as the design phase in order to avoid subsequent modifications. The certificate issued at the end of the conformity assessment process guarantees that the facility complies with current fire and explosion protection regulations.

During the final inspection before commissioning, the presence of ATEX certificates pursuant to NGM Decree 35/2016 (IX. 27.) on the safety requirements for equipment and protective systems intended for use in potentially explosive atmospheres must also be examined for every electronic component. As the final stage of the process, full compliance with the administrative steps under Government Decree 281/2024 (IX. 30.) on the official procedures for the construction of specific industrial structures is required in order to obtain the

occupancy permit. Technical difficulties arising during the certification procedure often stem from the lack of preparedness of domestic testing stations, highlighting the necessity of developing the laboratory infrastructure.

6. Conclusion

The exhaustive analysis presented in this study has highlighted that deficient or ambiguous domestic regulation imposes significant administrative burdens and cost increases on investors, thereby slowing the technological transition. The most critical deficiency is found in the field of excise taxation, where Act LXVIII of 2016 on Excise Duty, in the absence of a specific tax rate, creates economic uncertainty, hindering operators' long-term return-on-investment calculations and directly contributing to the temporary shutdown of the first domestic refuelling station.

An equally serious problem is that Hungary's National Hydrogen Strategy (ITM, 2021) does not mention the terms "fire hazard" or "explosion hazard" even once, suggesting that safety-technical aspects were not given sufficient emphasis alongside economic goals during strategic planning. This omission entails serious risks during the implementation phase, as safety is a fundamental prerequisite for the social acceptance of the technology. The deficiencies in the National Fire Safety Regulations (OTSZ), established by BM Decree 54/2014 (XII. 5.), also reveal that legislation has not kept pace with technological progress, as provisions specifically for HRSs have still not been integrated into the normative text (Nagy & Bencs, 2023).

Due to the fragmented nature of the regulatory environment, designers are forced to use analogies, which increases the risk of technical error and administrative rejection. Looking forward, it is indispensable to integrate hydrogen-specific provisions into relevant national legislation, particularly regarding the recording of quality assurance parameters in NFM Decree 17/2017 (V. 26.) on the quality requirements of motor fuels. From a professional perspective, it is recommended that the National Directorate General for Disaster Management (BM OKF) issue a specialized operational guide that incorporates the tactical elements described in this study into official protocols, thereby assisting firefighter preparation. Furthermore, it would be expedient to supplement the Technical Guideline for Fire Protection (TvMI) 13.5:2025.02.01 on Explosion Protection with an independent hydrogen chapter to clarify specific zone classification and sizing issues for the engineering profession.

The preparation of regulatory experts, the adoption of international best practices, and the closer integration of international standards (e.g. ISO 19880-1:2020) into the domestic legal order are essential for the safe proliferation of hydrogen infrastructure. The legislator must also resolve the anomalies in

environmental permitting to ensure that eco-friendly technologies do not suffer an unjustified competitive disadvantage due to bureaucracy. Ultimately, the basis of safe operation is full and verified conformity, which necessitates the involvement of accredited certification bodies and independent experts throughout the entire lifecycle of the technology. The rise of the hydrogen economy is not merely an engineering achievement but also requires the active, supportive cooperation of the legislator and the authorities. A true green transition in Hungary can only be realized within a coherent, transparent, and predictable regulatory environment.

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